Loss-Reduction Provisions of A Federal Earthquake Insurance Program

Final Report

Issued in Furtherance of the Decade for Natural Disaster Reduction

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LOSS-REDUCTION PROVISIONS OF
A FEDERAL EARTHQUAKE INSURANCE PROGRAM

Final Report

Prepared for

The Federal Emergency Management Agency (FEMA)

Under
Contract No. EMW-88-C-2872

by

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August 1990

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ACKNOWLEDGEMENTS

We wish to thank the sponsoring agency, the Federal Emergency Management Agency (FEMA), the project officer, Dr. A. Zeizel, the project liaison, J. Taylor, and the Advisory Panel for their superobligatory efforts on this project. We wish also to acknowledge the efforts of all National Earthquake Hazard Program (NEHRP) agencies, especially FEMA, the National Science Foundation, the United States Geological Survey, and the National Institute of Standards and Technology, for developing seismic safety programs and research to the stage that the viewpoints expressed herein were made possible. As clarified in the disclaimer, this acknowledgement does not imply that the positions represented in this report reflect those held by any of the above persons or organizations.

In addition, we wish to thank the following people for their assistance:

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ACKNOWLEDGEMENTS (Continuation)

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ACKNOWLEDGEMENTS (Continuation)

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EXECUTIVE SUMMARY

In anticipation of current proposed legislation concerning federal earthquake insurance or reinsurance, this report on the loss-reduction component of federal earthquake insurance programs was prepared by Dames & Moore under contract to the Federal Emergency Management Agency (FEMA) (No. EMW-88-C-2872). Significant assistance on this project was provided by the University of Southern California, University of Pennsylvania, George Washington University, Milliman & Robertson, Inc., and Risk Engineering, Inc.

Procedures utilized to conduct the study include a thorough examination of existing information on available earthquake hazard reduction activities and techniques, three meetings of a nationally recognized advisory panel, and a project workshop. The project workshop involved experts and representatives of many diverse agencies, organizations, and interests from throughout the country in order to construct acceptable findings. A nationally recognized Advisory Panel provided critical review of project progress and findings.

Major project findings include the following:

(1) There are cost-effective, technically credible earthquake loss-reduction measures (LRMs), chiefly in landuse and building practice, that are acceptable for inclusion in a federal earthquake insurance or reinsurance program. Table 1 summarizes those acceptable LRMs identified in this project. Figure 1 provides a small-scale seismic zonation map that suggests where the LRMs in Table 1 can be applied to zones of seismic hazard (numbered 0 through 4) throughout the United States.

(2) Current earthquake risk analysis techniques -- in spite of their uncertainties -- are acceptable for the evaluation of LRMs and the determination of both primary earthquake insurance rates and secondary earthquake insurance prices.

(3) Two primary vehicles exist for the effective inclusion of the fifteen LRMs into a federal earthquake insurance or reinsurance program. These are
   - o earthquake ordinances for state and local government adoption and enforcement and
   - o a system of partially risk-based insurance rates that provide financial incentives for the adoption and enforcement of earthquake ordinances.

(4) An enhanced federal program of earthquake loss-reduction can be justified by the resulting reduction of existing contingent federal liabilities, especially with respect to public and private non-profit facilities in higher risk seismic zones (2 and especially 3 and 4).

Based on project findings, we make the following recommendations:

(1) The fifteen LRMs listed in Table 1 should be incorporated into a federal earthquake insurance or reinsurance program.

(2) Small-scale maps for implementation of these LRMs throughout the nation should be developed by the insurance administrator, primarily on a scientific basis. Figure 1 could be used in the interim.

(3) FEMA should initiate an enhanced federal program designed to provide cost-effective LRMs and technical assistance and training to state and local governments. FEMA should seek the necessary resources to undertake this enhanced program.

(4) Activities identified in this report should be initiated or continued to facilitate or support the fifteen recommended LRMs.

(5) Earthquake risk methods for evaluation of LRMs and for primary earthquake insurance rating and secondary earthquake insurance pricing should be probabilistic -- i.e., evaluate all potentially damaging earthquakes. For developing equitable financial incentives for the recommended LRMs and for avoiding other administrative pitfalls, earthquake insurance rating maps should be similar to maps for LRM application, and both should be risk-based.

(6) In a primary federal earthquake insurance program, the earthquake insurance administrator should employ a combination of risk-based rates and earthquake ordinances in order to implement the recommended LRMs.

(7) In a secondary federal earthquake insurance program, possible ways of inducing LRMs include use of secondary pricing that reflects risks, agreements with state insurance regulators that risks be reflected in rates, and/or leverage from a combined primary and secondary program that requires earthquake ordinances.

(8) Continuous program monitoring, review, and improvement are essential features of any federal program initiated.

(9) Evaluation of the many issues -- in addition to loss-reduction -- related to the feasibility of a federal earthquake insurance program should be undertaken.

Table 1
Loss-Reduction Measures Recommended for
a National Earthquake Insurance Program

Landuse LRMs (Applicable only in seismic zones 3 and 4)

New Development

LRM 1 Require in high liquefaction susceptible zones that geotechnical techniques be used to minimize potential ground failures for

- o new commercial, public, and residential subdivision development and

- o major modifications of commercial, public and residential subdivision development. (Exceptions of scattered construction of single-family dwellings may be considered in legal and administrative versions of this loss-reduction measure.)

LRM 2 Use zoning ordinances, subdivision ordinances, and other techniques to control new development in active fault zones, high site-amplification, landslide and liquefaction susceptible zones.

Existing Development

LRM 3 Permit reconstruction or replacement of existing development in areas identified as active fault zones, high landslide, or liquefaction susceptible zones experiencing damage of more than 50% of replacement value only if the identified risk is reduced to an acceptable level. Consider purchase of existing damaged properties in high landslide susceptible zones unless suitable measures are used to protect existing development from damage.

LRM 4 Proscribe additions to buildings in areas identified as active fault zones, high landslide or liquefaction susceptible zones unless the risks are reduced to an acceptable level, except additions to single-family dwellings up to 50% of the replacement cost, which can be made without such risk reduction.

Building Practice LRMs

New Construction

LRM 5 Eastern model codes shall be encouraged to incorporate (adopt by transcription) the latest version of the NEHRP seismic provisions. All model codes should incorporate a geotechnical component that considers local site amplification effects on strong ground motion and minimization of potential ground failure effects.

LRM 6 Building regulatory authorities should adopt and enforce model codes that have adequate seismic provisions for buildings including one- and two-family dwellings and anchorage of mobile homes. The building code should apply also to repairs of earthquake-damaged buildings to assure that losses are not repeated in subsequent earthquakes.

Table 1 (Continuation)

New Construction (Continued)

LRM 7 In seismic zones 2, 3, and 4, new essential buildings and public schools, including colleges and universities, should be designed in conformance with current model code seismic provisions.

LRM 8 In seismic zones currently designated 2 with high seismic catastrophic loss potential (designated 2*) model codes should require the detailing requirements applied to zones of high seismicity.

LRM 9 For new construction in seismic zones 3 and 4, a building "hazard rating" must be disclosed to potential buyers well before the close of escrow.

Existing Construction

LRM 10 In seismic zone 4, local jurisdictions should institute ordinances with requirements for seismic retrofit of unreinforced masonry (URM) bearing wall buildings. These buildings should be required to be upgraded to a minimum level or else demolished within a 20-year period.

LRM 11 In seismic zone 4, local jurisdictions should institute ordinances for the securing/strengthening of building parapets and external ornamentation within a 20-year period.

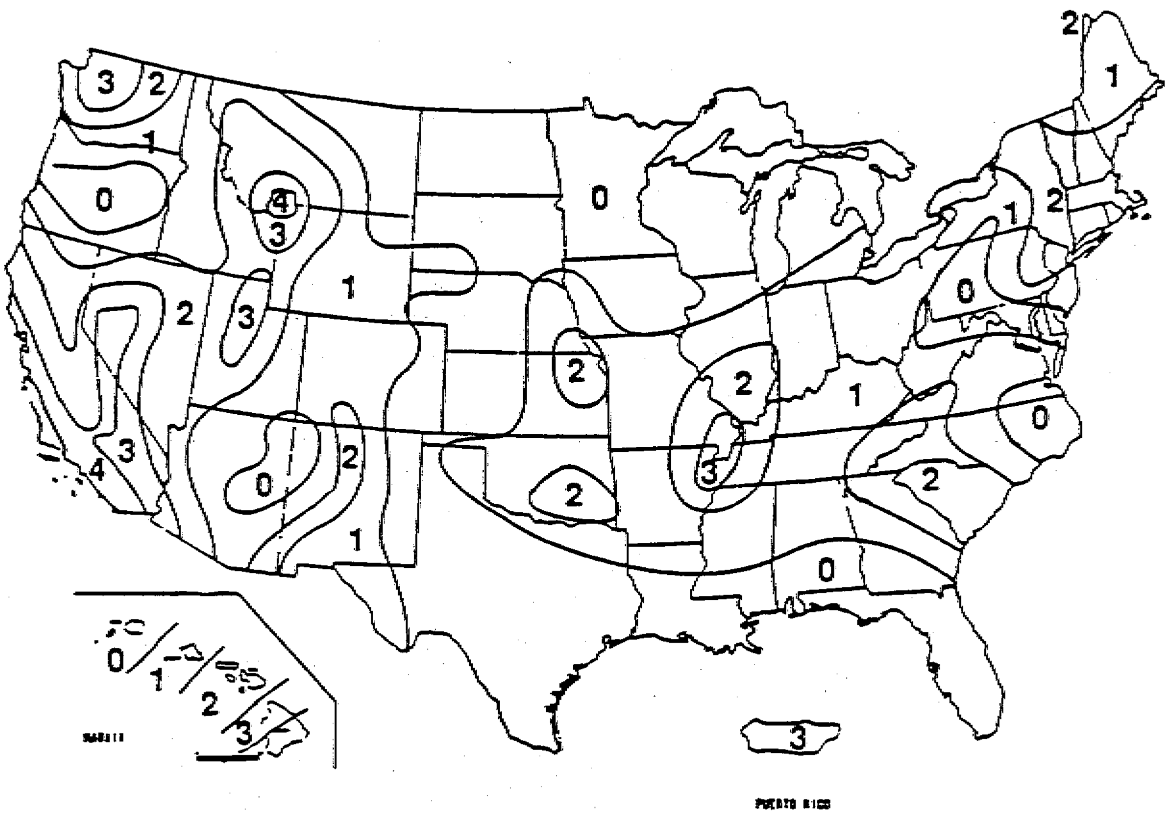
LRM 12 In seismic zone 4, potentially hazardous (other than URM) essential buildings and public schools, including colleges and universities, must be retrofitted or phased out within a 20-year period.

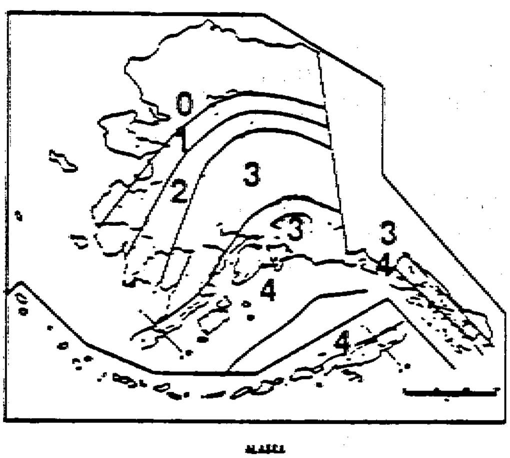
LRM 13 In seismic zones 3 and 4, inspections of buildings including one- and two-family dwellings and anchorage of mobile homes should be performed prior to significant financial commitment or property transfer and hence well before the close of escrow. A report to the potential buyer should indicate whether or not

a. the dwelling is anchored to the foundation,
b. unbraced cripple walls are present, and
c. gas water heaters (if present) are adequately braced or strapped to the framing.

LRM 14 In seismic zone 4, state law should require that gas water heaters in multi-family dwellings (new and existing) be braced or strapped to structural framing.

LRM 15 In seismic zone 4, concrete tilt-up construction which does not have adequate roof-to-wall anchors and continuity ties shall be required to be retrofitted within 10 years.





* EXPLANATION

For Adapting Figure C-1, We Have Used the Following Relationships Between Seismic Zones and Peak Horizontal Ground Accelerations:

Seismic Zone	Peak Ground Acceleration (Percentage of Gravity)	Shaking Hazard Level
0	< 0.05	Lowest
1	≥ 0.05 and < 0.1	
2	≥ 0.1 and < 0.2	
3	≥ 0.2 and <0.4	
4	≥ 0.4	Highest

Figure 1. Illustrative Seismic Zone Map for the United States
(Adapted * from "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA Publication 18 by the Building Seismic Safety Advisory Council, 1988)

PROJECT SUMMARY

The Congress of the United States is considering the establishment of a federal insurance program designed to reduce earthquake-caused mortality, morbidity, and economic losses and to protect homeowners, businesses, and financial and public institutions from sudden and disruptive catastrophic economic losses. In anticipation of this current consideration, the Federal Emergency Management Agency (FEMA) contracted for this study (Contract No. EMW-88-C-2872) in order to have addressed some of the key issues concerning federal earthquake insurance or reinsurance. Specifically, this study has been contracted to "identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporation of recommended loss-reduction provisions into a national earthquake insurance program" -- if one should be created by the Congress.

Major project goals were to

- o identify, evaluate, and recommend loss-reduction measures (LRMs) that are promising for incorporation into an earthquake insurance program involving the federal government,
- o indicate appropriate earthquake risk analysis methods for assessing and applying LRMs and for setting earthquake insurance rates, and
- o describe how recommended LRMs may be incorporated into a federal earthquake insurance or reinsurance program.

Loss-reduction is considered by many to be one of the major objectives of any earthquake insurance or reinsurance program involving the federal government. Many of the other objectives of such a program, such as reducing the Federal deficit, providing stability to homeowners and financial institutions after catastrophic earthquakes, and providing affordable insurance, involve considerations beyond the scope of this report.

Diverse views are held regarding loss-reduction in a federal earthquake insurance program. Specifically, views differ on

- o the cost-effectiveness of specific earthquake loss-reduction measures and of earthquake loss-reduction measures generally,
- o the feasibility of geological mapping of local seismic hazards, seismic building reviews, and other activities to support LRMs and to provide bases for earthquake insurance rate-setting (rating),

- o the proper role of the federal government, if any, in state and local landuse and building practices generally and those related to earthquake loss-reduction specifically, and
- o the feasibility of incorporating cost-effective LRMs into either a primary or a secondary earthquake insurance program. (In a primary earthquake property insurance program, the insurance is provided directly to the property owner; in a secondary earthquake insurance program, insurance is provided to the insurer.)

In order to understand these positions better, we have

- o held three meetings of a nationally-recognized advisory panel to identify and discuss diverse viewpoints regarding this study.
- o reviewed existing information on earthquake loss-reduction activities and measures,
- o identified from this information search loss-reduction measures that are technically sound,
- o subjected these technically-sound loss-reduction measures to economic analysis in order to determine which activities are cost-effective and who pays for and who benefits from these activities,
- o evaluated and revised selected measures at a workshop of experts and individuals from many diverse organizations throughout the United States,

As a critical part of these efforts, we have

- o identified fifteen LRMs that are technically sound, cost-effective, and politically and administratively feasible for inclusion in a federal earthquake insurance program,
- o identified activities needed to initiate, support or sustain these fifteen LRMs,
- o determined that earthquake risk analysis methods are currently adequate for LRM assessment for community use and for earthquake insurance rating,
- o clarified current contingent federal liabilities resulting from current federal disaster assistance and other federal policies and indicated how some of the activities required to initiate or to sustain recommended LRMs may justify an enhanced federal program of state and local programs and assistance to reduce these liabilities, and
- o demonstrated how the fifteen LRMs can be incorporated into earthquake ordinances which, along with the encouragement of risk-based rates, can serve to make the implementation of these LRMs consistent with a federal primary or secondary earthquake insurance program, and
- o provided forums permitting and encouraging the expression of a wide variety of viewpoints.

Forums for Clarifying Project Issues

Given the wide range of views on earthquake risk analysis methods, the acceptability of LRMs, the desirability of supporting activities for LRMs and for rating, and the feasibility of incorporating LRMs into a federal earthquake insurance program, no unanimity of results was possible. Instead, the project approach was to permit this wide variety of positions to be expressed, along with their rationales, so that these views could be used to modify project results or to clarify issues addressed.

For instance, a view that earthquake property loss-reduction may not be cost-effective has derived from the observation that seismic codes are life-safety based; therefore, performance of some buildings suffering total constructive loss from earthquakes is considered a success because no casualties were sustained. To address this viewpoint, we have emphasized economic criteria along with technical, administrative, and other criteria in determining the acceptability of LRMs. Past earthquake investigations have shown that buildings designed with little or no seismic resistance are much more likely to suffer higher degrees of damage -- as well as be life-threatening -- than are buildings designed to adequate current model seismic code provisions. Hence, this study concludes that a strong relationship exists between property-loss reduction and seismic safety even though model seismic codes could give more emphasis to damage control.

Risk Analysis Methods

This report contains a condensed section on earthquake risk analysis methods appropriate for a federal earthquake insurance program. Our examination of earthquake risk analysis methods has found that

- o earthquake risk analysis has advanced sufficiently over the past twenty years to provide an adequate basis for assessing LRMs and for determining earthquake insurance rates in spite of large uncertainties;
- o current techniques are adequate for the development of small-scale seismic zone maps for use by a federal earthquake insurance administrator in spite of some differences in approach;
- o seismic risk methods for inclusion in a federal earthquake insurance program should be probabilistic and should evaluate all potentially damaging earthquakes and likelihood of occurrence; otherwise, both benefits of LRMs and expected earthquake insurance losses could be either grossly underestimated or arbitrarily assigned; and
- o detailed engineering reviews of all buildings covered in a federal earthquake insurance program would be cost-prohibitive; moderate underwriting expenditures can provide a federal earthquake insurance program administrator with sufficient information for encouraging LRMs and for setting rates; and

- o program monitoring of exposures and losses is essential for improving loss-reduction efforts and establishing rates along with continual review and application of pertinent research findings.

Recommended Loss-Reduction Measures

We have identified fifteen LRMs, involving both improved landuse and building practices, that are suitable for inclusion in a federal earthquake insurance program. These are summarized in Table 1.

Some of the LRMs in Table 1, namely building code requirements, apply throughout the country; however, the cost-effectiveness of implementing special building code requirements in low seismic zones has been questioned. Figure 1 is used here to illustrate different seismic zones that can be used for the application of LRM requirements in a federal earthquake insurance program. Seismic zones 0 and 1 have the least earthquake strong motion hazards. The low level of hazards in these zones implies very limited long term benefits of LRMs. Consequently, requiring LRMs in these areas in exchange for the earthquake insurance benefit may as a rule be uneconomic. Nonetheless, there are benefits to inclusion of such regions in the building code process. These benefits are derived from uncertainties inherent in the seismic zonation process which are highlighted when extremely low probability damaging earthquakes occur in regions thought to be aseismic. When this occurs seismic zone designations can be changed appropriately to reflect improved information. Purchase of earthquake insurance at very low rates in low seismic hazard zones provides economic protection against extremely low-probability events.

Figure 1 is adapted from FEMA publications (95 and 96), "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings." It is intended to illustrate how the recommended LRMs become more stringent in the higher seismic zones especially zones 3 and 4. Other seismic maps, such as those found in the 1988 Uniform Building Code or the 1982 American National Standards Institute Code are more or less consistent with Figure 1.

In all such maps, portions of California, Alaska, and possibly Montana have the highest (zone 4) seismic zone designations. Portions of Arizona, Arkansas, Guam, Hawaii, Idaho, Illinois, Kentucky, Nevada, Puerto Rico, Tennessee, Utah, the Virgin Islands, Washington and Wyoming may be high (zone 3) or higher seismic zone designations. Regions east of the Rockies with seismic zone 2 designations with high catastrophic loss potential may include portions of states possibly affected by earthquakes in New Madrid, Missouri, or Charleston,

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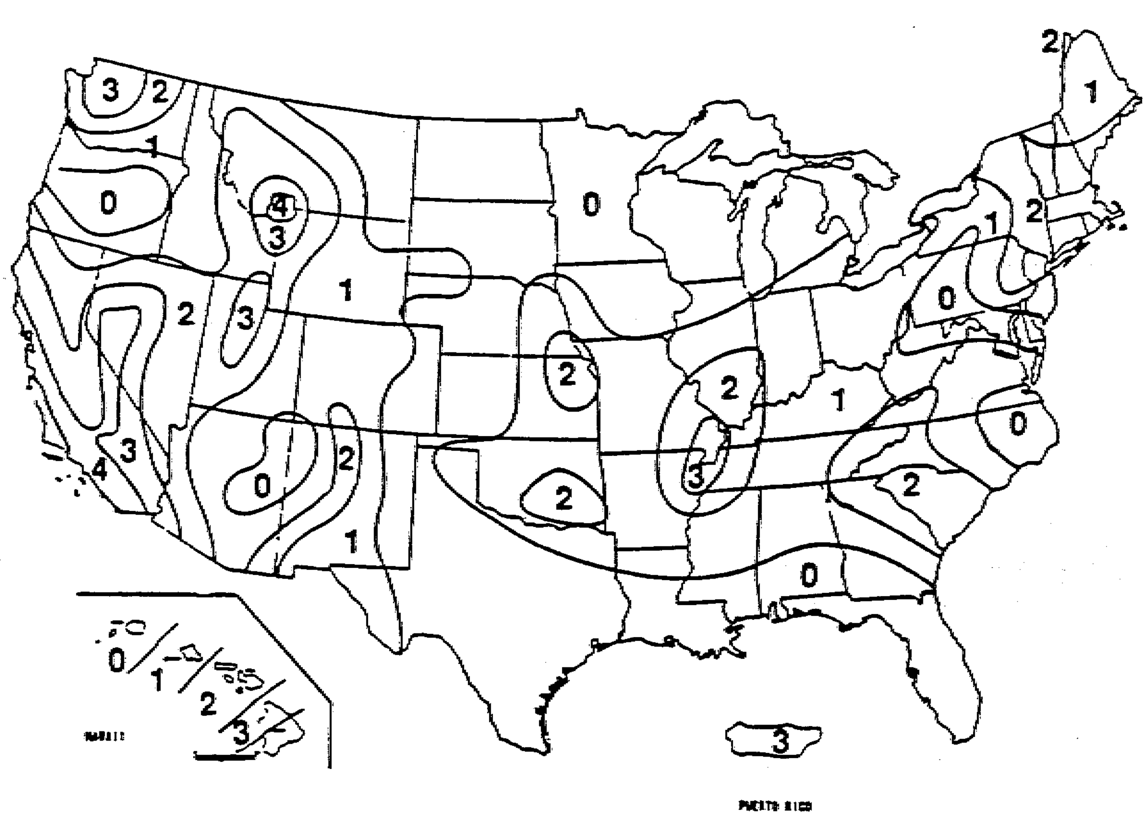

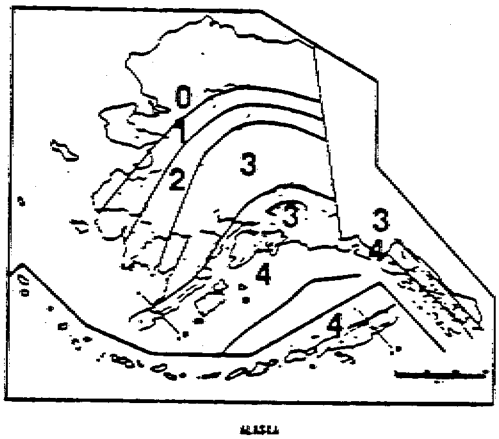

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Figure 1. Illustrative Seismic Zone Map for the United States

(Adapted * from "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA Publication 18 by the Building Seismic Safety Advisory Council, 1988)

South Carolina, or possibly the northeastern United States. Regions west of the Rockies having seismic zone 2 designations but with high catastrophic loss potential may include portions of Alaska, Oregon, Utah and Washington.

Figure 1 could be used on an interim basis for the implementation of LRMs in a federal earthquake insurance program. One of the first steps in such a program should be the establishment of national seismic zone maps. Methods for developing these maps are currently available and being updated. These maps are technically acceptable for the LRMs recommended in this project.

Economic analysis has determined the following loss-reduction measures as being most cost-effective:

- o adoption of, compliance with, and enforcement of adequate seismic design provisions in new construction (LRMs 5, 6, 7, 8, and 9),
- o seismic retrofit of unbolted and/or poorly anchored wood-frame residences in seismic zone 4 (LRM 13), and
- o use of geotechnical techniques (supported by landuse planning) to minimize severe landslide, liquefaction, and/or subsidence hazards in seismic zone 4 (LRMs 1 and 2).

The remainder of the LRMs presented in Table 1 were determined to be adequately cost-effective and acceptable to representatives of a broad range of geographic regions and interests.

The LRMs recommended provide guidance to FEMA on which LRMs to include in a federal earthquake insurance program. Administrative discretion should be used with respect to such expressions as "50% of replacement value." Substitution of "50% of market value," for instance, may prove to be administratively easier. The LRMs recommended are expressed generally enough to represent a consensus among the professional engineers, landuse planners, economists, and state and local administrators who participated on the project. Additional specificity in terms used would require additional legal, public policy, scientific, and engineering discussion and analysis.

The emphasis in LRMs recommended lies in practices for new construction, especially with respect both to adoption, compliance, and enforcement of adequate seismic code provisions and to minimization of potential ground failure hazards during new development and major modifications of existing construction.

We have developed a list of major types of potentially hazardous construction for purposes of characterizing "potentially hazardous" construction as referenced in Table 1. This list is provided in Table 2. Other potential "hazard rating" categories include "Conforming"

Table 2

Potentially Hazardous Building Construction Classes Identified for Public Policy Purposes

(1) Buildings with unreinforced masonry bearing walls which do not have complete or adequate load paths for seismic forces.

(2) Concrete tilt-up or reinforced masonry structures with flexible roofs. Flexible roofs include those of wood or steel deck without concrete fill. Structures having one or more of the following inadequate features:

  (a) wood ledgers used in cross-grained bending or tension,

  (b) no bolts or anchor straps for anchorage of walls to roof diaphragm,

  (c) excessive spacing or inadequate capacity of roof to wall anchors,

  (d) chord elements that are discontinuous (not supplied with continuity plates, etc.), and/or

  (e) inadequate connection of tilt-up wall panels to foundation.

(3) Non-ductile concrete frames -- concrete moment-resisting frames not conforming to the detailing provisions of the 1976 or later editions of the Uniform Building Code (UBC) and American Concrete Institute (ACI) Standard 318-77, including appendix A, (1977 edition or later) including "pre-cast" frames.

(4) Buildings with "soft" or "weak" first stories -- particularly those having story strengths less than 65 percent of the strength of the story above, as per 1988 UBC.

(5) Buildings having unreinforced or inadequately braced parapet walls or inadequately attached exterior ornamentation.

(6) Buildings with inadequately attached or rigidly attached (inadequate allowance for story drift) exterior glazing or pre-cast concrete, masonry, or stone curtain wall panels.

(7) Unreinforced masonry "infill" exterior walls.

(8) Unreinforced masonry interior partitions or "infill" walls in stairwells and elevator shafts.

(9) Buildings where no lateral force resisting system is present or can be identified either in the whole building or in a story of the building. Buildings in which the seismic lateral force resisting system is incomplete or has significant gaps that could allow portions of the structure to collapse.

(to current model seismic code provisions), "Nonconforming" (to these provisions), and "Retrofit" (to 65 percent of current model seismic design force requirements). For jurisdictions in seismic zones 3 and 4 who comply with LRMs or other model seismic codes, the distinction between "Conforming" and other hazard rating categories will be between new and existing buildings. Disclosure requirements of LRM 9 may further assist in providing disincentives for the prolonged use of potentially hazardous buildings in seismic zones 3 and 4. A major objective of a federal earthquake program is to reduce over time the seismic vulnerability of the extremely large stock of existing potentially hazardous construction, especially in higher seismic zones.

Activities Supporting Recommended LRMs

Loss-reduction measures cannot be implemented without adequate information, resources, and organizational capability. A set of activities needed to initiate, sustain, and/or support the fifteen recommended LRMs are listed in Table 3.

As with the recommended LRMs, the supporting activities are defined generally enough to achieve consensus among representatives of a broad range of interests and diverse geographic regions. Further administrative and professional effort is required to define such expressions as "minimum population" and "high liquefaction susceptibility".

The supporting elements described in Table 3, for the most part, involve a continuation of programs already underway in conjunction with both NEHRP programs and state and local practices. For instance, mapping scales required by the supporting elements are no larger than 1:24,000, and then only in higher seismic risk zones (zones 3 and 4) with significant urban development. Considerable data and maps already exist to help fulfill these requirements. As defined, the lack of full supporting elements should not delay implementation of the most significant and cost-effective LRMs in Table 1. In view of the considerable progress in NEHRP programs and the potential for future progress, the activities in Table 1 should be regarded primarily as LRMs that are cost-effective to implement -- even considering costs of supporting activities. Research that suggests additional cost-effective ways to reduce losses from earthquakes should be used to periodically evaluate and improve the LRMs included.

The Community Basis of LRM Enforcement

We recommend for adoption by appropriate state and local bodies earthquake ordinances analogous to those adopted under the national flood plain management program within the National Flood Insurance Program (NFIP).

Table 3

Activities Needed to Support Recommended LRMs

Activities Supporting Landuse LRMs
(except for L1, applicable only in seismic zones 3 and 4)

L1 For the entire United States, development of small scale maps (1:5,000,000) of ground motion, evaluated by an expert panel.

L2 For urban areas with a minimum population (e.g., 50,000) development of intermediate scale maps (1:100,000) of ground motion that include examination of local geological effects on strong ground motion (e.g., maps of relative site velocities for different spectra).

L3 Compilation and as necessary development of large scale maps (1:24,000) of Quaternary surface faulting within a 50-mile band outside the perimeter of urban areas having a minimum population. Compilation and development of intermediate scale maps (1:100,000) elsewhere in seismic zones 3 and 4.

L4 Compilation and development of large scale liquefaction and landslide high seismic susceptibility maps (1:24,000) for urban areas having a certain minimum population. Greater attention should be placed on quantitative interpretation of such expressions as "high susceptibility." Areas mapped should be large enough to accommodate short-term growth in undeveloped areas around the city.

L5 Construction of information databases and transfer mechanisms so that the foregoing maps may be readily available and understandable to local officials, realtors, developers, insurance companies, and the general public.

L6 Requirement that general plans include a seismic safety element that sets development policy for local geological hazards including high relative site response factors, fault zones, and regions of high liquefaction and/or landslide susceptibility.

L7 Development of requirements for areas identified as active fault zones, and high landslide or liquefaction susceptible zones that a geologic/geotechnical report be prepared for critical facilities, high-occupancy buildings, new subdivisions, and major modifications of high-occupancy (and/or critical) buildings, and that these be reviewed by a suitable licensed professional.

L8 Development of guidelines for preparation and review of geologic/geotechnical reports.

L9 Provision of resources for state and local programs, procedures, and staffing to effect LRMs.

Table 3 (Continuation)

Activities Supporting Building Practice LRMs

B1 Definition of "potentially hazardous buildings" as in Table 2.

B2 Definition of seismic zone 2* as those seismic zone 2 areas with high seismic potential at extended recurrence intervals and/or with high seismic loss potential.

B3 Definition of criteria and a program for seismic evaluation and retrofit of existing buildings.

B4 Provision for limitations on liability of local jurisdictions and their building official(s) when they provide and permit criteria (as in B3) for evaluation and retrofit design which is less stringent than building code requirements for new construction.

B5 Permission for voluntary seismic upgrades without mandated upgrades for non-safety related functions.

B6 Support for the development of programs and procedures and of professional state and local building staffing to effect LRMs.

B7 Support for dislocated or disadvantaged tenants during seismic retrofit programs.

B8 Continued research directed at reducing costs for seismic construction, both new and existing.

B9 Continued work to incorporate a geotechnical component into model seismic code provisions.

B10 Continued research into the development of codes that emphasize property damage control and maintenance of function over and above critical life-safety protection.

The concept of earthquake ordinances recognizes that these LRMs are implemented at state and local levels and that public agencies, as opposed to financial institutions, are the appropriate enforcers of these LRMs. The concept also recognizes that earthquake loss-reduction implementation programs require coordination among various agencies within municipalities, even though most of the currently active earthquake loss-reduction programs are handled exclusively by building safety departments. The LRMs in Table 1 are accordingly designed for adoption by state or local community-based programs. Especially in higher seismic zones, individuals, firms, municipalities, or states may, based on life-safety, economic, political, or legal reasons, decide to use higher seismic standards than those implied in Table 1. Moreover, selected insurers may provide detailed rate credits for seismic safety practices. Table 1 LRMs generally require some degree of regulation and cover a wide range of possible cases -- not merely unique motivations or circumstances.

Loss-Reduction through Enhanced Current Public Policy

We review existing earthquake loss-reduction programs at federal, state, and local levels in order to examine the framework within which project objectives can be achieved. We maintain that, in spite of the progress that has been made in these programs, further efforts at a federal level could be made to strengthen these programs and reduce existing contingent federal liabilities. A strengthened federal program could in turn provide support for the higher cost activities listed in Table 3 through reduction of these liabilities. Provision of resources for state and local programs, procedures, in particular, and staffing to effect LRMs (L9 and B6 for landuse and building practices, respectively) could be initiated based on such an enhanced federal program.

Current public policy involves no direct federal involvement in earthquake insurance and has many constraints on local adoption and enforcement of earthquake ordinances and promotion of loss-reduction activities. These include lack of adequate staffing, competition within the building construction industry to keep front-end construction costs as low as possible, and resistance to landuse planning that adjusts real estate values. One of the more significant constraints is the Federal financial contribution toward repair, restoration, and replacement of damaged facilities. Once the President has declared a disaster, Section 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (P.L. 100-707) commits the federal government to financing not less that 75 percent of the net eligible costs of repair, restoration, reconstruction, or replacement of public facilities and private nonprofit facilities. Expectation of the 75 percent federal cost share serves as a disincentive to the local and state application of adequate seismic standards to construction and/or retrofit of public and selected private nonprofit buildings.

The Stafford Act does require that loss-reduction measures in the form of local codes, specifications, and standards be applied to recovery efforts financed through any disaster loan or grant under the provisions of the Act. The Act provides 50 percent financial support for hazard mitigation activities and requires natural hazard evaluation in those areas receiving assistance under the Stafford Act.

The January 5, 1990, Executive Order 12699 on Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction requires that each Federal agency responsible for the design and construction of a new Federal building shall ensure design and construction with appropriate seismic standards. Further, new buildings constructed and leased for Federal use or constructed with Federal financial assistance or regulated by a Federal agency shall appropriately use seismic safety standards. Nationally-recognized private sector standards and practices shall be used when possible or adequate local building codes. Implementation of this order should reduce earthquake losses to Federal, Federally subsidized, or Federally regulated new buildings.

While the Stafford Act and Executive Order 12699 reflect considerable progress with respect to loss-reduction efforts, the very significant contingent federal liabilities resulting from current federal policies indicate the need for increased federal controls to reduce these liabilities. Additional resources are needed to achieve the specific goal of reducing existing federal liabilities associated with potential earthquakes, even without a federal earthquake insurance program.

Federal disaster relief policy, along with other federal policies such as taxation, Small Business Administration (SBA), and Federal Deposit Insurance Corporation (FDIC) policies, supports a significant federal government interest in state and local landuse and building practices. Additional federal action to strengthen landuse and building practices for earthquake loss-reduction is warranted. Financial support for training programs and for local staffing, as was provided during the early implementation of the Clean Air Act, is an example of such needed Federal program strengthening. Part of the support for LRMs identified in Table 1 can be provided through a wide variety of federal programs specifically designed to reduce existing contingent federal liabilities.

Federal Involvement in Earthquake Insurance

One possible change in programs would involve the federal government in earthquake insurance. This would initially increase direct federal liabilities in the short term but with premium inome and loss-reduction could decrease them over the long term. In order to discuss how this may affect the implementation of loss-reduction measures, we consider

- o earthquake risk analysis methods and their application in the selection and monitoring of LRMs and in insurance rate-setting, and
- o how insurance rating influences the implementation of loss-reduction measures.

We use expected reductions in annual losses to ensure that recommended LRMs are cost-effective. However, traditional seismic loss estimation methods (expected annual loss and probable maximum loss methods, respectively) are not suitable for earthquake insurance rating purposes. Instead, new multisite methods exist which are better able to incorporate both expected annual losses and extreme fluctuation in those losses into a coherent framework for earthquake insurance rating. These methods can better deal with risk diversification and rate reduction issues. These methods also can be used to determine suitable prices in a secondary earthquake insurance context. However new these methods are with respect to earthquake, they are similar to methods used since the onset of the National Flood Insurance Program.

Protection of the public, insurance rate-reductions, and economic stability of public and private entities, with resulting benefits to individuals, would be major goals of a federal earthquake insurance involvement. Another goal -- the principal focus of this project -- would be to reduce future losses through the incorporation of loss-reduction measures into federal earthquake insurance program involvement. Without these measures, expected primary earthquake losses would increase, thus affecting adversely the safety, health, and welfare of the nation's citizens and the economic stability of the nation's public and private entities.

Two primary vehicles exist whereby implementation of LRMs such as those listed in Table 1 can be made compatible with and incorporated into a federal earthquake insurance program: (1) adoption of and enforcement of state and local earthquake ordinances and (2) a system of partially risk-based insurance rates -- rates that discourage poor seismic construction quality and encourage adoption and enforcement of adequate seismic standards. Without a system of partially risk-based rates, federal earthquake insurance involvement would be seriously incompatible with the loss-reduction measures proposed. With partially risk-based rates, communities could be further encouraged to adopt, comply with, and enforce loss-reduction ordinances. With primary federal earthquake insurance programs, a combination of partially risk-based rates and ordinances can be strongly encouraged, as in the NFIP. With secondary federal earthquake involvement, e.g., federal reinsurance provided to primary earthquake insurers, earthquake ordinances can only indirectly be encouraged such as through secondary pricing that reflects risks of exposures to primary insurers.

Various goals can be reached with the combined encouragement of earthquake ordinances and a system of partially risk-based rates. These include short-term goals of improving the protection of the people and ensuring the nation's economic stability in the face of potential catastrophic earthquakes and the long-term goals of reducing the losses resulting from earthquakes.

Recommendations

Based on project findings, we make the following recommendations:

(1) **The fifteen LRMs listed in Table 1 should be incorporated into any Federal earthquake insurance involvement.** These LRMs are scientifically and technically valid, practical and cost-effective and have been critically reviewed by experts and representatives from a wide variety of geographic regions and interest groups. The primary loci of direct enforcement for these LRMs are state and local government authorities, not financial institutions.

(2) For implementation of these LRMs, **small-scale seismic zone maps for the nation should be developed** primarily on scientific and statistical bases. Figure 1 should be used in the interim and would be adequate for starting a federal earthquake insurance involvement incorporating LRMs. State and local jurisdictions can require additional seismic protection.

(3) **FEMA should initiate an enhanced federal program specifically designed to provide cost-effective LRMs to reduce existing contingent federal earthquake-related liabilities.** FEMA should seek the necessary legislative mandates and resources to undertake this enhanced program. This report identifies many of those liabilities and

demonstrates how they can be cost-effectively reduced to the benefit of the federal taxpayer. This recommendation supports Administrative and Congressional deficit-reducing themes discussed in Darman (1990) and GAO (1989a and b) and further supports the loss-reduction goals described in the January 5, 1990 Executive Order on "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction." An enhanced program of this sort would provide many of the supporting elements needed for incorporation of LRMs into any federal earthquake insurance program and would further ensure that public buildings, as well as private nonprofit buildings, serve as examples of good seismic practice.

(4) Should a federal earthquake insurance program be initiated, other **supporting activities** as indicated in Table 3 **should be initiated or augmented.** In almost all instances these supporting elements are not marginally expensive. Cost considerations should not delay implementation of the fifteen LRMs. In other instances, especially B6 -- support for the development of programs and procedures and professional state and local building staffing to effect LRMs, these should be considered as part of the deficit-reducing program suggested in recommendation (3).

(5) We recommend that **probabilistic multisite risk analysis methods be used for insurance rate-setting**. Although actuarial and public policy analyses are needed to determine how rates are to be structured in a federal earthquake insurance involvement, preliminary conclusions pertinent to LRMs and rating methods were drawn. In order to account for both expected earthquake losses and potentially extreme fluctuations in those losses. Inventory of exposures should occur during application to the program. Second, we recommend **partially risk-based rates** that support and sustain the fifteen LRMs proposed. To the extent that rates reflect risks, seismic zone maps in recommendations (2) and (4) will be similar to or mirror rating maps. In contrast, to the extent that territorial or jurisdictional or other considerations enter into this public policy analysis, seismic zone maps suggested for LRMs may diverge somewhat from those for rating. To the maximum degree possible, a single mapping program should be used for both LRM application and insurance rate-setting. This offers decided administrative advantages over using widely divergent maps for LRMs and for rates.

(6) The fifteen LRMs proposed in this project can be incorporated into state and local government earthquake ordinances. **In a primary federal earthquake insurance**

program, we recommend that the administrator employ a combination of partially risk-based rates and insurance availability conditional on cost-effective LRMs being adopted and enforced and by **earthquake ordinances.** These methods are analogous to methods effectively being implemented under the NFIP. A mandatory primary program and, hence, a monopolistic program, has the potential disadvantage that an administrator may wish to cut program costs that would otherwise be incurred in a competitive market situation. These include modest costs of underwriting partially risk-based rates. As a result, rating incentives for cost-effective loss-reduction measures must be built into the objectives of such a mandated program.

(7) **In a secondary federal earthquake insurance program,** a federal insurance administrator will be faced with a difficult challenge in incorporating LRMs. **The administrator may use secondary pricing that reflects risks, agreements with state insurance regulators to ensure that risks are reflected in rates, or leverage from a combined primary and secondary federal earthquake insurance program in order to require earthquake ordinances.** We regard the incorporation of LRMs into a secondary federal earthquake insurance program as being feasible but challenging.

(8) **Program monitoring, review, and improvement are essential** features of the program envisaged here. Developments are ongoing in mapping earthquake hazards, assessing earthquake risks, and improving cost-effective risk-reduction technologies. A federal earthquake insurance program containing a loss-reduction element should systematize pertinent program information and should periodically review and evaluate this information against developments to assure continuing and improving program efficacy in loss-reduction.

(9) **Examination should be undertaken of the many issues** -- over and above loss-reduction -- **related to the feasibility of a federal earthquake insurance program.** Actuarial, economic, and public policy analyses, for instance, are needed to examine various detailed issues concerning the protection of the Federal Treasury, the provision of affordable earthquake insurance, and the reduction of post-earthquake instabilities in the financial sector of the economy. Issues of mandating insurance purchase requirements should also be examined. Further consideration should be given to how a government insurance program may and should differ from a private sector or competitive program.

1.0 INTRODUCTION AND OVERVIEW

This report constitutes the last of a series of deliverables under Federal Emergency Management Agency Contract No. EMW-88-C-2872 entitled "Loss-Reduction Provisions of a National Earthquake Insurance Program."

1.1 Contractual Background

Current concerns prompting this study are described in the contract "Statement of Work" as follows:

> The Federal Emergency Management Agency (FEMA) is considering issues related to earthquake insurance. This reflects current discussions of the need for a national earthquake insurance or reinsurance program involving the Federal Government. The Congress has been giving more emphasis to the use of insurance to deal with natural disaster losses instead of Federal disaster assistance. One of the major considerations by Congress and the Executive branch prior to approval of any Federally-assisted earthquake insurance or reinsurance program may well be whether loss-reduction is an integral part of the program's goals, objectives and procedures. . . . Any national earthquake insurance program would require a significant financial commitment by both the Federal Government and the private insurance sector. The incorporation of loss-reduction provisions would reduce potential loss exposure to both parties and provide a basis for lower insurance premiums to the policyholders. (Contract, page 9)

Because

> There are different views on how best to include loss-reduction provisions within a national earthquake insurance program, what those provisions should be, and . . . whether such provisions would be technically, economically, socially, and politically feasible. (Contract, page 9)

FEMA contracted this study in order to

> identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporaton of recommended loss-reduction provisions into a national earthquake insurance program. (Contract, page 9)

More specifically,

> The objective of this study is to identify, evaluate, and recommend feasible earthquake loss-reduction provisions, including safe land use and building practices, that can be incorporated into a national earthquake insurance or reinsurance program involving the Federal Government and the private insurance industry. (Contract, page 10)

The scope of the study, as described in the contract, was relatively broad:

> This study shall identify specific loss-reduction measures that can be applied to different structural classes of buildings, including almost every type of walled and roofed building. The scope should include, at a minimum, new construction, existing hazardous buildings, and critical buildings such as those used for emergency operations, police, fire, and medical services, public assembly, and schools. The study shall identify loss-reduction measures that can be taken by State and local governments, the private sector, and individual homeowners. The scientific, technical, social, economic, and politi-

cal aspects of the loss-reduction strategies and measures shall be addressed. Pertinent legal issues shall be discussed. (Contract, page 10)

Deliverables submitted prior to this report (as required by the contract) have included the following working drafts:

- "Project Workplan: Loss-Reduction Provisions of a Federal Earthquake Insurance Program" dated November 30, 1988.
- "Summary of Principal Issues: Relating to the Incorporation of Loss-Reduction Provisions into a National Earthquake Insurance Program" dated May 31, 1989.
- Report on earthquake risk assessment and portrayal methods (Contract, Task IV, page 12) entitled "Risk Analysis Methods for a Federal Earthquake Insurance Program" dated May 31, 1989.
- Report of project team efforts to "assemble and evaluate all promising strategies and measures . . . for earthquake loss-reduction" (Contract, Task III, page 11) entitled "Promising Loss-Reduction Measures In a Federal Earthquake Insurance Program," Volume I, Working Copy, July 1, 1989, and Volume II, Working Copy, July 20, 1989.
- Report of Project Workshop results entitled "Workshop: Loss-Reduction Provisions of a National Earthquake Insurance Program for the Federal Emergency Management Agency and the Federal Insurance Administration," September 30, 1989.
- Two drafts of the final report, January 15, 1990 and March 31, 1990.

This document, constituting the "Final Report" required by the contract,

> proposes earthquake loss-reduction provisions along with a recommended strategy for incorporation into a national insurance or reinsurance program. . . . The supporting scientific, technical, socioeconomic, legal, and public policy data, analysis, findings, conclusions, and rationale shall be included. A general plan for continuing evaluation and modification of the loss-reduction provisions if they are incorporated into a national earthquake insurance program shall be included as an appendix. (Contract, page 20)

In an effort to provide the reader with important background information, the remainder of this section reviews the current status of federal involvement in earthquake-related loss-prevention and disaster relief (1.2), describes limitations of the scope of this study (1.3), summarizes the methods used in conducting this study (1.4), and presents an overview of the content of this report (1.5).

1.2 General Background -- The Status Quo

Consideration of the possible need for a national earthquake insurance or reinsurance program involving loss-reduction provisions acknowledges the fact that current earthquake loss-reduction programs are fragmentary. This fragmentariness in earthquake loss-reduction programs results from a number of factors which contribute to make up current earthquake-related policy in the United States. Specifically, current fragmentariness is due to

- o local/municipal "locus of control",
- o the variety of sources of building codes,
- o the economies of scale necessary to implement loss-reduction,
- o irregular sensitivity of political bodies to earthquake-related concerns,
- o constraints on the insurance system, and
- o current disaster relief policies.

In order to understand the relationship between current efforts and a proposed national program, one must first be familiar with the status quo. Recognition of challenges within the status quo is made possible through considerable progress in research and other National Earthquake Hazard Reduction Programs (NEHRP). However, frank discussion of problems in the implementation of loss-reduction is needed to determine why fragmentariness currently exists and how modified programs, including a federal earthquake insurance program, can assist in meeting challenges for loss-reduction programs. The following discussion reviews these factors in order to establish the context in which this study was conducted.

Locus of Control

Currently, the implementation of loss-reduction measures occurs on individual and local levels. Although implementation of loss-reduction measures (as defined in section 1.3) would continue to occur at local levels, the purpose of this project requires assessing loss-reduction programs in terms of their connection to federal insurance programs. As a result, several issues related to the locus of control of loss-reduction programs require discussion. At the project workshop and elsewhere, participants emphasized the need to explain how loss-reduction measures incorporated into a federal insurance program could adequately serve national needs. Put otherwise, how would the loss-reduction program relate appropriately to Boston, Minneapolis, and Atlanta as well as to San Francisco and Anchorage?

In spite of many educational and post-disaster response advances, and other selected advances in implementing loss-reduction measures, we maintain that current earthquake loss-reduction programs are to a large degree fragmentary. This fragmentariness is reflected by

- o inadequate seismic code provisions for most jurisdictions east of the Rocky Mountains (a problem significantly being addressed in recent developments by model code organizations);

- o the absence of seismic retrofit ordinances for unreinforced masonry buildings (or for other potentially hazardous buildings) except in selected California municipalities (with more ordinances likely after the October 17, 1989, Loma Prieta earthquake);
- o the relative ineffectiveness of seismic elements of landuse planning programs, even in many California municipalities (Wyner and Mann, 1983); and
- o the extremely large stock of potentially hazardous structures that, as a consequence of the above factors, continues to increase.

Sources of Building Codes

The fragmentary application of seismic codes to local jurisdictions is due in part to the variety of sources used to develop codes. Three key model code organizations that publish building codes are

- o the International Conference of Building Officials (ICBO), which publishes the Uniform Building Code (UBC);
- o the Building Officials and Code Administrators (BOCA), which publishes the BOCA National Building Code (formerly, the Basic Building Code -- BBC), and
- o the Southern Building Code Congress International (SBCCI), which publishes the Standard Building Code (SBC).

One major concern in developing a national program is how federal officials should work with these model code organizations and a variety of other organizations (e.g., Structural Engineers Association of California, Building Seismic Safety Council, and the American Society of Civil Engineers) concerned with model code development.

Economies of Scale

Earthquake loss-reduction activities require economies of scale (here, especially, decreasing output costs per unit of labor or capital added) which typically include (1) large front-end costs in order to make the activities effective and (2) high degrees of specialization required to implement loss-reduction activities.

Large front-end costs are required to support such activities as construction and retrofitting to seismic standards. Unfortunately, those who must bear these costs are often hard-pressed to justify the expenditures. Fundamentally, large capital outlays may not be within the financial capabilities of many stakeholders with limited liquidity, including low-income residents, small businesses, and nonprofit organizations. Moreover, returns to be gained from high front-end costs may not be realized within short time frames. Many of these "returns" may not be investment returns, but rather "spillover" benefits to those who occupy buildings, whether as tenants or as visitors, or to the government, which may spend less for disaster clean-up. Builders, contractors, and short-term owners may not realize the benefits of their outlays. In those cases where front-end costs prevent loss-reduction activities, dangers resulting from potentially hazardous buildings and sites are to a large degree involuntary, since stakeholders visiting, living, and working in these facilities individually have extremely limited control over siting and construction practices.

Coping with seismic design requires that design engineers, building officials, building inspectors, contractors, carpenters, masons, main workers, and steel fabricators, among others, be familiar with the technical elements of seismic code provisions. Even greater expertise is typically required for seismic rehabilitation programs.

Thus, earthquake loss-reduction typically requires investments of significant capital and technical expertise. Such funding and expertise are often not available at the local level. Successful implementation would be very expensive if individuals or firms were to undertake seismic loss-reduction programs on their own without organized social resources. These economies of scale have been proferred as one reason why seismic provisions of building codes may be required, since it would be very inefficient for consumers to make these decisions on an individual basis (See Milliman and Roberts, 1985).

Timing of Earthquake Policy Development

Another cause of current fragmentariness is explained by champions of loss-reduction programs who often speak of waiting for <u>windows of opportunity</u> -- typically earthquake disasters -- to promote major legislation, stronger ordinances, and improved private industry practices. (See Cheney and Whiteman, 1987; Olson et al., 1988.) With a few exceptions, economic, political, and social systems are sensitive to earthquake risk issues only on an irregular basis -- often in the unfortunate context of the disaster itself. Exceptions, for example, occur largely in states west of the Rocky Mountains, principally in California, and are expressed through building code practices, emergency preparedness drills, and other pre- and post-disaster preparations which call attention to earthquake issues, existing commercial and residential earthquake insurance purchases, and selected instances of seismic retrofit.

Private Market Insurance System Considerations

Insurance system considerations are many, but principally include financial and functional limitations on insurance companies in acting as enforcers of loss-reduction programs. Financial limitations include the inadequate total capacity of the insurance market to cover potential claims in a voluntary earthquake insurance market that lacks substantial risk diversification. Specifically, the risks are not sufficiently spread geographically to limit the catastrophic loss potential to the total portfolio of an insurance company from single earthquakes. This problem of inadequate capacity can to some extent be offset by reinsurance, but the reinsurance market also has a limited capacity and raises reliability concerns because reinsurers are currently largely unregulated. Business cycles in this reinsurance market (see Cheney and Whiteman, 1987; Anderson et al., 1981) have dramatic effects on earthquake insurance availability and prices. Federal taxation and other policies exacerbate this capacity problem to the extent that insurers are less able to build up long-term reserves to meet potential earthquake losses.

Functionally, insurance companies are not necessarily in the best position to enforce earthquake loss-reduction programs. Since they are private, competitive, regulated companies subject to antitrust and other constraints, they cannot mandate earthquake insurance purchase, they operate under severe limitations on the extent to which they can share information for rate-setting and other purposes, and as private firms they have no direct concern for the spillover (e.g., public) benefits of earthquake loss-reduction programs. Within this context, decisions regarding how much to spend on underwriting and rating are largely private, and company policies in this regard may vary considerably. Reinsurers are often in an even less effective position, since they may have difficulty obtaining exposure data from primary insurers.

Disaster Relief Considerations

Causes of fragmentariness in earthquake loss-reduction efforts partly as a consequence of disaster relief programs include the following:

(1) Prior to 1988, post-disaster funding (i.e., the use of funds to pay for existing earthquake damage) was characterized by the absence of a preventive inducement.

(2) The 1988 Robert T. Stafford Disaster Relief and Emergency Assistance Act includes provisions for preventive loss-reduction. Nevertheless, for certain categories of operations (e.g., those including publicly-owned or private nonprofit buildings) there exists a strong disincentive to engage in property loss-reduction measures, because disaster relief assistance assumes a large (75 percent) payback for damage incurred should a federal declaration be made.

(3) Prior to 1990, federal buildings like state and local buildings only occasionally served as models of good seismic practice.

(4) Many segments of the population appear to misunderstand the limitations of how much federal and state governments are obligated to pay after a disaster.

These considerations suggest that, to a larger degree than is desirable, earthquake costs are "externalized," i.e., not borne by those who assume the risks. (See Atkisson and Petak, 1981 and Burby et al., 1990 for confirming evidence.) As a result, these constraints serve as disincentives to the implementation of loss-reduction activities. For smaller municipalities, owing to inadequately developed risk management, these disincentives may be not explicitly perceived as such. Nevertheless, reliance on state and federal programs for catastrophic earthquake loss-reduction, especially outside California, suggests that the disincentives, among other factors mentioned, are operable. (See Burby et al., 1990.) For purposes of background clarification, the following discussions of the 1974 Disaster Relief Act as modified in 1988 by the Robert T. Stafford Disaster Relief and Emergency Assistance Act and of Executive Order 12699 (January 5, 1990) are provided. These discussions presuppose that genuine needs are met through federal disaster assistance. This report by no means provides a comprehensive account of disaster relief programs. The implications of current practices for loss-reduction are, however, important in understanding how these practices may be improved.

Robert T. Stafford Disaster Relief and Emergency Assistance Act
(P.L. 93-288 as amended by P.L. 100-707)

Once the President has declared a disaster, Section 406 of the Stafford Act commits the federal government to financing not less than 75 percent of the net eligible cost of repair, restoration, reconstruction, or replacement of **public facilities and private nonprofit facilities.** This "net eligible cost" is based on

> the design of such facility as it existed immediately prior to the major disaster and in conformity with current applicable codes, specifications, and standards . . ..

Of particular importance is the fact that reconstruction costs are not confined to restoring the facility to its original design, but may include redesign to current applicable codes, specifications, and standards. Additionally, funding is not limited to 75 percent of allowable recovery costs.

In the context of loss-prevention programs, Section 406

- o provides for general risk reduction alternatives which include not only repair and replacement but also relocation when
    - o the facility is and will be subject to repetitive heavy damage, and
    - o the overall project is cost effective;
- o requires that currently applicable standards be used in federally assisted repairs or replacements.

In section 409, the use of "applicable codes, specifications, and standards" is required as a condition of any disaster loan or grant under the provisions of the Act. Thus, the Stafford Act requires that loss-reduction measures be undertaken for damaged structures for which federal grants or loans are made available. These standards, codes, and specifications must "apply uniformly to all similar types of facilities within the jurisdiction of the owner of the facility" (FEMA, March 1989, p. 11637).

In the context of earthquake **insurance**, the Stafford Act, as amended, also includes references. Section 311 of P.L. 100-707 requires that applicants for assistance under section 406 shall

> assure that, with respect to any property to be replaced, restored, repaired, or constructed with such assistance, such types and extent of insurance will be obtained and maintained as may be reasonably available, adequate, and necessary, to protect against future loss to such property.

Determination of "availability, adequacy and necessity" requires certification by the appropriate state insurance commissioner responsible for regulation of such insurance.

Section 404 of the Stafford Act provides federal support for **post-disaster hazard mitigation activities** related to **undamaged public and private nonprofit buildings and all commercial, industrial, and residential buildings**. Specifically, the Act states that

> the President may contribute up to 50 percent of the cost of hazard mitigation measures which the President has determined are cost-effective and which substantially reduce the risk of future damage, hardship, loss, or suffering in any area affected by a major disaster. Such measures shall be identified following the evaluation of natural hazards under section 409 and shall be subject to approval by the President. The total contributions under this section shall not exceed 10 percent of the estimated aggregate amounts of grants to be made under section 406 with respect to such major disaster.

Additionally, Section 409 (formerly part of section 406 under the 1974 Disaster Relief Act) provides for the **pre-disaster natural hazard evaluation** process in which state and local recipients of disaster loans and grants

> shall agree that the natural hazards in the areas in which the proceeds of the grants or loans are to be used shall be evaluated and appropriate action shall be taken to mitigate such hazards including safe land-use and construction practices, in accordance with standards prescribed or approved by the President after adequate consultation with the appropriate elected officials of general purpose local governments, and the State shall furnish such evidence of compliance with this section as may be required by regulation.

In theory, Section 409 may be used to enhance efforts to reduce earthquake risks after a major flood, hurricane, or other non-earthquake disaster. However, after a thorough examination of this clause in practice, Atkisson and Petak (1981) concluded that the hazard mitigation evaluation process generally has been applied to only the peril which led to the disaster for which recipients received relief and not to possible future disasters. Additionally, Brower et al. (1986) have concluded that past (pre-Stafford Act) hazard mitigation planning activities under the above clause have had little relationship to federal funding decisions. As a result, local constituencies have had little incentive to conduct natural hazard evaluations. (See Burby et al., 1990 for a broader survey.)

In review, The Stafford Act commits the federal government to significant financial liabilities following a presidentially-declared disaster due to earthquake. The act is primarily applicable to only damaged public and private nonprofit buildings. It does however promise that seismic replacement and retrofit can be required, given adequate current codes, specifications, and standards. Developments after the 1989 Loma Prieta, California, earthquake are very promising for earthquake loss-reduction activities. (See The State/ Federal Hazard Mitigation Survey Team, 1990.) In addition, with state insurance regulator certification, insurance purchase can be required for repaired or replaced buildings so that a large share of the contingent federal liabilities for these buildings can be transferred to state and local governments (FEMA, March 1989, p. 11639).

<u>Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction</u>
(Executive Order 12699 of January 5, 1990)

In support of federal efforts to develop and promulgate earthquake-resistant standards for new construction, the President issued Executive Order 12699. This order requires that

> Each Federal agency responsible for the design and construction of each new Federal building shall ensure that the building is designed and constructed in accord with appropriate seismic design and construction standards. (President, 1990)

The order specifies that local building codes affecting seismic design and construction be applied to all new construction of buildings to be "leased for federal uses or purchased or constructed with federal assistance." The order also applies in the federal regulation of the structural safety of buildings. In effect, Executive Order 12699 enhances loss-reduction efforts by exercising federal controls; however, only federally-related new construction is affected by the Order.

Limitations of Current Federal Involvement

The principal goal of current disaster policy is to ensure that economic stability be restored in regions affected by a disaster. Concerns with respect to health, life, safety, and environmental matters also exist. As a consequence, through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, the federal government has accepted liability for financing a significant proportion of the cost of post-disaster recovery of public and private nonprofit facilities in presidentially-declared disaster areas. In practice, this federal liability serves as a strong financial disincentive for state and local governments to engage in pre-disaster earthquake loss-reduction projects. (See Cheney and Whiteman, 1987.)

Unfortunately, as will be discussed throughout the remainder of this report, federal controls over activities which could reduce federal liabilities are not commensurate with these potential federal liabilities. (See Burby et al., 1990.) This suggests that stronger controls are needed over the activities which could reduce these federal liabilities. At the same time, advances in science and engineering, made possible largely through national programs such as the NEHRP (and also private industry programs), have made it feasible to advance the loss-reduction measures found in this report.

As currently written, the Stafford Act mandates that communities affected by disasters employ hazard mitigation measures to reduce the risk from future disasters. These measures are not standardized; they are location-specific. Also, they are politically negotiated by state and federal officials rather than designed by damage mitigation specialists, and then they are amassed in a Hazard Mitigation Plan early in the recovery process rather than well-formulated prior to the disaster. From the standpoint of federal liability, given the Stafford Act and other existing federal policies, the federal government has a clear interest in state and local programs that affect potential earthquake losses, including those pertaining to state and local development, adoption, and implementation of seismic loss-reduction measures.

Additionally, current federal policy tools provide no means to achieve broad scale implementation of loss-prevention activities because they are mandated only for new construction of federally leased, assisted, or regulated buildings and for rebuilding in localities declared federal disaster areas by the President. Instead of being proactive and supporting the implementation of loss-reduction efforts prior to earthquake events, the current disaster policy is primarily reactive and triggered by unusual events. (See Burby et al., 1990.)

Finally, while necessary to support recovery efforts, the current policy has no provisions to address primary and secondary effects in areas other than Presidentially declared disaster areas. Thus, by itself, current policy is even insufficient to deal with the full impacts of single disasters. The Stafford Act, therefore, is not by itself a policy that is capable of preparing the entire United States for a catastrophic earthquake.

In order to protect the United States from the effects of a catastrophic earthquake, the current disaster policy is clearly insufficient. What is needed is a mechanism which reduces both long-term and short-term losses associated with earthquakes. Such is the fundamental goal prompting this study.

Conclusions

Public policy vehicles currently available for reducing earthquake losses have not yet produced a coherent large-scale or national program of loss-reduction implementation. In addition, a pure market solution to the earthquake loss-reduction problem is not feasible, since neither earthquake insurance nor loss-control markets operate according to idealized conditions (e.g., adequate knowledge by individual consumers, absence of "adverse selection," absence of significant spillover effects). Current fragmentariness of earthquake loss-reduction programs is a problem that needs to be addressed with sensitivity to local and regional differences. Consequently, this report examines public policy vehicles available for guiding a national program. Section 5.0 includes discussions of how current public policy vehicles may be augmented given a federal role in earthquake insurance.

1.3 Project Scope

The goal of this study is to

> identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporation of recommended loss-reduction provisions into a national earthquake insurance program.

Throughout the conduct of this project, questions arose regarding the depth and breadth of results achievable. As specified in the project contract, the scope of the study was to include

- o different structural classes of buildings, including almost every type of walled and roofed building.
- o at a minimum, new construction, existing hazardous buildings, and critical buildings such as those used for emergency operations, police, fire, and medical services, public assembly, and schools.
- o measures that can be taken by state and local governments, the private sector, and individual homeowners.
- o The scientific, technical, social, economic, and political aspects of the loss-reduction strategies and measures....
- o Pertinent legal issues....
- o information and research available nationally and internationally. (Contract, page 10)

Early in the course of this project steps were taken to identify the boundaries within which this study would be conducted.

Definition of Loss-Reduction Measure

One primary issue addressed in determining project scope was how the expression "loss-reduction measure" was to be used. In the Project Workshop we defined a loss-reduction measure as requiring **a physical activity or restraint thereon that reduces expected earthquake losses.** This definition accords with the definition of "hazard mitigation" for purposes of implementing the Stafford Act. (See FEMA, March 1989, p. 11633.) The definition has both a physical and a statistical element. There must be a physical intervention in the built environment and statistical evidence that the measure reduces loss.

This definition requires that a proposed loss-reduction measure be specified in terms of a "fix" -- some action or set of activities that improve the expected seismic performance of buildings or otherwise are expected to reduce earthquake losses directly. For new buildings, this may involve selecting less hazardous sites, improving site foundations, or applying seismic codes or other techniques in order to improve the seismic performance of the building system and its nonstructural systems and contents and to reduce life-safety hazards. Avoiding especially hazardous sites in new construction falls under this definition insofar as alternative sites selected would be assessed to have lower risks. Density limitations may fall under this definition to the extent that both the expected risks are catastrophic ones and that the alternatives available to high-density developments reduce these expected catastrophic losses. For existing buildings, the fix may involve altering usage, securing equipment, instituting means to control fire following earthquake, and/or seismic retrofit of structural elements.

Many activities such as research, mapping, workshops, and the like are required to initiate, support, and/or sustain loss-reduction activities. We call these <u>supporting elements</u>. For instance, educational and training programs of various sorts may be required so that the many participants in building practices -- architects, building officials, structural engineers, developers, owners, contractors, and subcontractors -- are aware of and experienced in complying with model seismic code provisions.

We also call both loss-reduction activities and supporting activities <u>earthquake hazard reduction activities</u>. Hence, a number of earthquake hazard reduction activities exist which, although integral to the process of loss-reduction, are not themselves loss-reduction activities. For instance, research into the development of base-isolation techniques is an important earthquake hazard reduction activity that makes technically feasible the loss-reduction activity base-isolation techniques in seismic design or retrofit.

The distinction between loss-reduction measures and supporting elements is vague in some instances in which supporting elements arguably may be categorized as loss-reduction measures. For instance, development of adequate seismic provisions in model codes is included as a loss-reduction measure insofar as some local communities unfailingly adopt and enforce these model codes. In contrast, inclusion of seismic safety elements in comprehensive master plans cannot be a loss-reduction measure unless this inclusion can be shown to lead to physical actions or restraints thereon that reduce expected losses.

A broader definition of loss-reduction measure may be suitable for a more comprehensive project. For example, an activity that reduces total losses associated with earthquakes is suggested in the Selkregg et al. (1984) account of mitigation as "a management strategy to balance current actions and expenditures with potential losses from the future hazard occurrences." This broader definition would require consideration of administrative costs, insurance system costs, front-end structural and geotechnical engineering costs, marginal research, mapping, educational costs, and costs of potential instabilities to financial systems. Some of these considerations have entered into the selection of promising loss-reduction measures. Consideration of the total cost of large-scale loss-reduction programs would require many investigations beyond this project scope.

Primary and Secondary Losses

Within the limitations of this definition of loss-reduction measure, this study is principally concerned with building losses (i.e., costs for repair and/or replacement of buildings) resulting directly from strong ground motion or permanent ground displacement (not from tsunamis, seiches, or flooding generally). We do not address utility or lifeline network losses, nor do we emphasize secondary losses resulting from building damage (e.g., casualties, fire damage, business interruption, governmental downtime, unemployment, mortgage defaults, business insolvencies, and economic ripple effects generally), even though these financial concerns are worth examining in greater detail elsewhere. (See Section 5.1 and Appendix C.) Post-disaster programs are discussed in this report only to the extent that the 1988 Stafford Act contains a mitigation element for which significant funds may be available for the implementation of LRMs.

In the scope of the project as clarified in the project workplan, we examine a variety of structures, whether identified by

- o structural class, including almost every type of walled and roofed building;
- o age, including both existing hazardous buildings and new construction; and
- o function, including commercial/industrial, residential, and critical public and special private-sector nonprofit buildings (e.g., hospitals).

We do not examine a variety of infrastructure facilities, whether private or public, including

- o such electric power facilities as power plants and substations, and
- o oil, sewage, natural gas, water, or communications buried pipelines or conduits.

Among losses, we specially examine

- o direct property losses to (damage to and collapse of) buildings and contents, including those resulting from landuse policies.

These direct property losses are very important causes of deaths and injuries -- matters of the utmost importance in community safety programs. We also examine

- o other selected secondary losses (as a derivative concern) including
  - o mortgage defaults,
  - o fire following earthquakes, and
  - o business interruption costs or costs of governmental discontinuity;
- o costs of reducing losses; and
- o premium costs.

We do not directly examine

- o damage to infrastructures including utility systems and secondary losses due to their failure (including casualties),
- o secondary losses to key sectors of the economy as a consequence of direct primary losses to buildings and contents,
- o loss implications of various proposed programs to reduce economic ripple effects of catastrophic earthquakes,
- o loss implications of alternative post-disaster emergency/claims adjustment procedures, and
- o specific cost estimates of underwriting in a primary or secondary reinsurance program.

Although we certainly endorse programs that deal with tertiary needs to reduce financial instabilities and improve post-disaster emergency procedures, the goal of this project is to examine loss-reduction measures that reduce <u>primary</u> earthquake losses, and to that extent secondary earthquake losses. We have defined the expression "loss-reduction measure" with this limitation in mind, but we encourage other studies to examine proposals to reduce economic ripple effects of earthquakes and other large-scale disasters and to improve emergency management procedures. In section 5.0, we explain how the objective of ensuring financial stability on a nationwide basis after a large catastrophic earthquake provides a major reason why incorporation of loss-reduction provisions into a federal earthquake insurance program is considered in this project.

The entire issue of rating in an earthquake insurance program involving the federal government requires many investigations beyond this study. This study confines itself to an examination of risk methods suitable for earthquake insurance rating and to key discussions of the role of rates as either powerful incentives or disincentives for undertaking loss-reduction measures. Although the extremes of (a) very detailed underwriting or (b) virtually no underwriting are not supported in this report, no precise underwriting costs have been developed.

Financial Surpluses in an Insurance Program

Another topic not within the project scope pertains to possible financial reserve developments in any federal earthquake insurance involvement. This exclusion leads to the following limitations:

- o our inability to determine whether or not earthquake insurance purchase should be mandatory,
- o limitations on our ability to examine possible consequences of mandatory earthquake insurance purchase such as who pays for and who benefits from this monopolistic setting,
- o our inability to estimate with any degree of accuracy total costs associated with any of the possible types of federal insurance involvement, and
- o our inability to determine if funds to support loss-reduction program administration would be derived from the insured or the general taxpayer or both.

With respect to the last consideration, we do maintain that some of the costs of incorporating loss-reduction measures may be borne by a taxpayer-based program specifically designed in a cost-effective manner to reduce existing contingent taxpayer liabilities.

Feasibility of Federal Insurance

Although this project addresses generally how loss-reduction provisions may be incorporated into a federal earthquake insurance program, we do not address the much broader topic of whether or not a federal earthquake insurance program is feasible. This much broader topic may include many public policy, legal, economic, actuarial, and risk analyses that include discussions of many of the topics excluded from this project, such as

- o loss and cost implications of various proposed programs to reduce economic ripple effects of catastrophic earthquakes,
- o advantages and disadvantages of other alternative federal earthquake program changes such as strengthened federal legislation to control existing contingent taxpayer liabilities associated with earthquakes,
- o economic and political implications of the role of government as an "insurer" or "reinsurer," a role more traditionally assigned to business,
- o public policy and socioeconomic considerations affecting how rates should be estimated in a federal program,
- o legal implications of various specific proposals for federal earthquake insurance involvements, and
- o the extent to which a federal earthquake insurance involvement combined with disaster assistance would solve all problems associated with very large potential earthquake losses.

<u>Types of Federal Earthquake Insurance Involvement</u>

To a limited extent, the project scope includes discussion of various types of federal earthquake insurance involvement, including

(1) revision of the <u>status quo</u> (including the 1988 Stafford Disaster Relief and Emergency Assistance Act),

(2) the federal government as primary insurer,

(3) the federal government as reinsurer, and

(4) some combination of (2) and (3).

In considering these involvements this report does not include a detailed account of all possible stakeholder liabilities under all four types of federal earthquake insurance. Additionally, in examining these four involvements, we do not examine claims adjustment and other post-disaster emergency procedures and other key features of disaster relief policy. Nor does this report thoroughly examine all earthquake-related policies or the Stafford Act, which from the limited standpoint here reflects progress over previous disaster relief policy (which had less of a loss-reduction component).

Since current contingent federal and state liabilities are a direct consequence of existing disaster relief provisions and tax statutes, the <u>status quo</u> must be regarded as a set of circumstances that contains various potential strengths, liabilities, problems, and public policy implications. The broader decision procedures used in this study treat the status quo as one of many alternatives to be considered. Through consideration of the public policy implications of the status quo, justification can be found for strengthening the mitigation component of federal programs and thus taking advantage of the knowledge gained through NEHRP (National Earthquake Hazard Reduction Program) programs.

The strengths of NEHRP programs are not the topic under current discussion. Nevertheless, this report recognizes that advances in the many disciplines supporting earthquake loss-reduction efforts have been significant in the decades since the 1964 Good Friday Alaskan earthquake and the 1971 San Fernando Valley earthquake. It is presupposed in this report that federal disaster relief programs provide needed post-disaster assistance to state and local governments, to small businesses, to private nonprofit organizations, and to individuals with limited liquidity. Still, consideration of both earthquake loss-reduction and of earthquake insurance suggests possible significant improvements in current federal programs -- improvements that build on past efforts.

1.4 Brief Summary of Methods and Procedures

In order to achieve the goals of this project, a significant effort was directed toward identifying, defining, and assessing feasible loss-reduction provisions and developing strategies for incorporation of recommended loss-reduction provisions into a national earthquake insurance program.

- A project team was assembled. Team members made very thorough searches of planning, scientific, and engineering information, in order to identify and exhaustively evaluate earthquake hazard reduction activities which could be useful in loss-reduction programs. Steps were taken to ensure that these hazard reduction activities apply to diverse regions of the country, to diverse building usages, and to diverse landuse and building practices. This search produced a collection of 96 earthquake hazard reduction activities for consideration.

  The project team used expert judgment to select, synthesize, and restate hazard reduction activities as a smaller number of more technically credible loss-reduction measures (LRMs) to be subjected to more rigorous analysis. During the course of this process LRMs naturally fell into two groupings -- Landuse Measures and Building Practices. Consistent terminology was applied throughout the two groupings, and supporting elements were restated so that practices needed to implement the LRMs could be encouraged. (See Section 4.2.)

  The project team developed an interactive socioeconomic risk-and-decision model in order to evaluate the technically promising loss-reduction measures on two grounds -- economic efficiency and economic allocation. The analysis provided important information regarding the cost-effectiveness of candidate LRMs and estimated costs and benefits to various key stakeholders (e.g., the general taxpayer, lending institutions, owners, tenants, insurers). This information was then compiled for presentation at a project workshop.

Concurrently,

o We held three meetings of an **Advisory Panel** whose nationally recognized members represent a broad range of professions, interests, and geographic regions. (See Appendix A for biographical sketches.) The main purpose of the Advisory Panel was "to ensure that the broad range of scientific, engineering, planning, insurance industry, and public policy information and viewpoints [were] considered in the study." (Contract, p. 11) We did not ask the Advisory Panel to concur with project findings, and this report reflects only their inputs, not necessarily their viewpoints.

  We held the **first meeting** of this panel on January 25, 1989. At this meeting the panel reviewed the project workplan and, in an open discussion, considered the scope of the study and the evaluation criteria for identifying promising loss-reduction measures. Throughout the project, some participants wished to restrict the project scope to consideration only of residential construction and to obviate all discussion of the relationship between rates and LRMs.

  At the **second Advisory Panel meeting**, held on June 8, 1989, panel members were introduced to preliminary results of project team efforts to identify loss-reduction measures, a review of the methods being used, and supporting documentation. The panel reviewed, in particular, the Issues and the Risk Analysis working reports.

o On August 15 and 16, 1989, we held a **Project Workshop** composed of recognized experts and interested and affected parties representing a very broad spectrum of interests, professions, and geographical regions in order to review and comment on previous project findings. In particular, those findings pertain to proposed loss-reduction provisions and their strategy for implementation in a national earthquake insurance program. The workshop was to provide for further consideration of the views of diverse interest groups and help assure that the proposed measures are professionally supportable, and acceptable to communities, the insurance industry and policyholders. The workshop was structured to encourage the introduction of new information and innovative ideas.

o The Project team synthesized, in a **draft** of this **report**, results of previous project steps. Specifically, these procedures resulted in the identification of a number of loss-reduction measures (LRMs) considered to be promising in some sort of federal program. These include LRMs involving both landuse planning and building activities, covering all geographic regions including both existing buildings and new developments, and covering residential, commercial/industrial, and institutional buildings. Also included are supporting elements, i.e., activities or measures required to initiate, support, or sustain promising LRMs. (Section 4.0) These promising LRMs are here regarded as applicable in defining potential "earthquake ordinances" (earthquake-resistant standards) for various portions of the country. In section 5.0, we examine how earthquake ordinances fit into various types of potential federal earthquake insurance involvements.

o On January 18, 1990, a **third meeting of the Advisory Panel** was held to review and discuss the content of the draft report in order to ensure that the results of the study would fully meet the contractual requirements in the project charge. At this meeting, lively exchanges took place regarding

- the possible role of earthquake insurance rate incentives for either encouraging or discouraging LRMs,
- how risk-based rates reflecting landuse LRMs should be encouraged along with risk-based rates reflecting building practice LRMs,
- how a federal insurance program differs significantly from a private insurance program,
- how direct federal rate-setting in a secondary federal insurance program may usurp rights of state insurance regulators,
- the extent of a federal interest in state and local practices,
- whether or not the draft report unintentionally exaggerates weaknesses in current federal programs at the expense of their strengths, and
- whether or not the fifteen recommended LRMs were acceptable to scientists, engineers, economists, and state and local officials over a wide geographic region.

- On March 31, 1990, a revised **final draft** was submitted for review by the Advisory Panel, the project officer, and, through the project liaison, to federal officials on the interagency task force on earthquake insurance.

1.5 Summary of Content

This report

- examines risk methods for both assessment of LRMs and for earthquake insurance rating,
- analyzes earthquake hazard reduction activities on technical, administrative, social, economic, political, and legal grounds as a means to develop recommended loss-reduction measures, and
- for the fifteen recommended LRMs, identifies general strategies whereby these can be incorporated into a national earthquake insurance program.

Section 2 addresses the topic of risk analysis as it applies to earthquake-related (seismic) concerns. Rather than simply summarizing currently available risk analysis methods and their functions, strengths, and limitations, this discussion stresses the suitability and application of various risk methods for the assessment of the cost-effectiveness of loss-reduction measures and for insurance rating. Specifically,

2.1 outlines the basic steps in risk analysis, describes the types of seismic risk analysis methods available, addresses questions of uncertainty in seismic risk analysis in insurance contexts, and recommends applications appropriate to implementation of loss-reduction measures and earthquake insurance.

2.2 examines the application of risk analysis methods to evaluating and setting earthquake insurance rates under different contexts of federal involvement.

2.3 addresses earthquake hazards mapping activities essential to incorporating loss-reduction provisions in a federal earthquake insurance program.

Section 3 identifies earthquake hazard reduction activities and analyzes these on technical, administrative, and economic grounds.

3.1 summarizes the process used to identify, define, and assess possible loss-reduction provisions appropriate for inclusion in a national program for insurance or reinsurance.

3.2 reviews the results of thorough efforts to identify earthquake hazard reduction activities which would satisfy the definition of loss-reduction measure and which, on technical and administrative grounds, also appear to be worth further examination as possible recommended LRMs.

3.3 reviews the process of socioeconomic analysis of these possibly acceptable LRMs, details the methods used to estimate costs and loss reductions, and reports the findings of socioeconomic analyses conducted to determine whether or not the technically feasible LRMs could be considered cost-effective.

Section 4 reviews the procedures used to ensure that recommended loss-reduction provisions would be considered acceptable on political and legal as well as social, economic, technical and administrative grounds and identifies loss-reduction provisions which potentially could be incorporated into a national insurance or reinsurance program.

4.1 describes the stakeholder analysis conducted in conjunction with this study.

4.2 presents the results of this analysis.

4.3 describes the Project Workshop at which cost-effective LRMs were discussed, revised, and refined to be acceptable to a wide range of knowledgable and interested parties.

4.4 presents a set of loss-reduction measures (LRMs) and necessary supporting activities that can be used in developing "earthquake ordinances" or earthquake-resistant standards for communities throughout the country.

Section 5 considers how loss-reduction provisions may be incorporated into three general types of federal earthquake insurance constructs.

5.1 presents an overview of the possible roles the federal government could play in the provision of earthquake insurance and discusses how the incorporation of LRMs fits generally into federal earthquake insurance and disaster relief objectives.

5.2 reexamines current earthquake-related policies and contingent federal liabilities, reemphasizes the fragmentariness of current national earthquake-loss-reduction policies, suggests means through which existing programs to effect many of the supporting elements of an LRM program, and recommends enhancement of those programs specifically to reduce in a cost-effective manner existing contingent federal liabilities.

5.3 considers how the rate structure of an earthquake insurance program will affect the implementation of such loss-reduction provisions as are recommended in this report.

5.4 considers as one major change in public policy the federal government as a primary earthquake insurer and how LRMs may be incorporated into such a primary federal earthquake insurance program.

5.5 addresses how LRMs can be incorporated into a secondary federal earthquake insurance programs.

2.0 SEISMIC RISK ANALYSIS METHODS IN A FEDERAL EARTHQUAKE INSURANCE PROGRAM WITH A LOSS-REDUCTION COMPONENT[1]

Seismic risk analysis methods and their possible applications in a federal earthquake insurance program involving a loss-reduction component are central to this project. Risk analyses are needed to answer such questions as:

- o Will the implementation of a loss-reduction measure be cost-effective and a sound policy decision? How is this affected by differences in seismic zone?
- o How will the implementation of proposed LRMs affect various stakeholders?
- o How can equity among stakeholders be assured in a rate-setting system for earthquake insurance?
- o To what extent can a rate-setting system for earthquake insurance consider both catastrophic losses that may occur in the near term and expected losses over the long term?

This section uses findings developed in Eguchi et al., (1989) and in the project workshop in order to help answer these questions by discussing:

- o the types of risk methods available and their applications and limitations,
- o risk methods appropriate for assessing LRMs and for use in setting insurance rates, and
- o risk mapping considerations.

Section 2.1 outlines the processes and methods involved in seismic risk analysis. We maintain that two decades of science and engineering have reduced uncertainties in seismic risk analyses, but that systematic efforts, such as post-disaster damage and loss studies, are desirable to reduce uncertainties further (NRC, 1989; Eguchi et al.,1989. In FIA, 1971, uncertainties in seismic risk analysis methods were considered to eliminate any consideration of a federal earthquake insurance program with a loss-reduction component.) We illustrate the linkages between risk analysis methods, loss-control, and insurance and then summarize project recommendations for uses of risk analysis.

Section 2.2 describes the types of methods suitable for earthquake insurance rate-setting. Because such rating requires comparison of reserves with all possible earthquake losses affecting them, these are probabilistic methods, not probable maximum loss (PML) or

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1. The reader who desires fuller details of the risk analysis methods discussed here may refer to the project report by Eguchi et al. (1989).

other deterministic methods. Fuller accounts of earthquake insurance rating methods are provided in Eguchi et al. (1989) and Taylor, Hayne, and Tillman (1990).

Section 2.3 discusses pertinent mapping considerations. For the application of loss-reduction measures, we recommend initially small-scale consensus maps as shown in Figure 2-5. Progress on such maps may soon include information regarding local shaking hazards and seismicity. (See Whitman, 1989.) Hence, small-scale maps should be constantly reviewed and updated. In higher seismic zones (3 and 4), larger-scale maps of clear local potential ground deformation hazards may be suitable. Research on estimating probabilities of various degrees of permanent ground displacement and on associated losses is desirable to make microzonation more effective in a federal earthquake insurance program. At first glance, and even at a small scale, seismic maps for LRMs are different in kind from seismic maps for insurance rate-setting; however, making radically different maps for rates and LRMs would have severe administrative weaknesses in a federal earthquake insurance program.

2.1 Risk Analysis Methods: Applications and Limitations

This subsection provides an overview of

- o steps required in risk analysis,
- o types of risk methods available,
- o major uncertainties of interest in a federal insurance context, and
- o recommended risk analysis methods and uses.

In Section 3 we use risk analyses to identify cost-effective LRMs for incorporation into a federal earthquake insurance program. In Section 5, we show how risk analyses may be used to develop partially risk-based insurance rates as one major tool for the incorporation of LRMs into this federal program.

A fuller discussion of detailed risk analysis methods available is found in the working report developed for this project.

Basic Processes in General Risk Analysis

Figure 2-1 provides an overview of the essential steps in risk analysis.

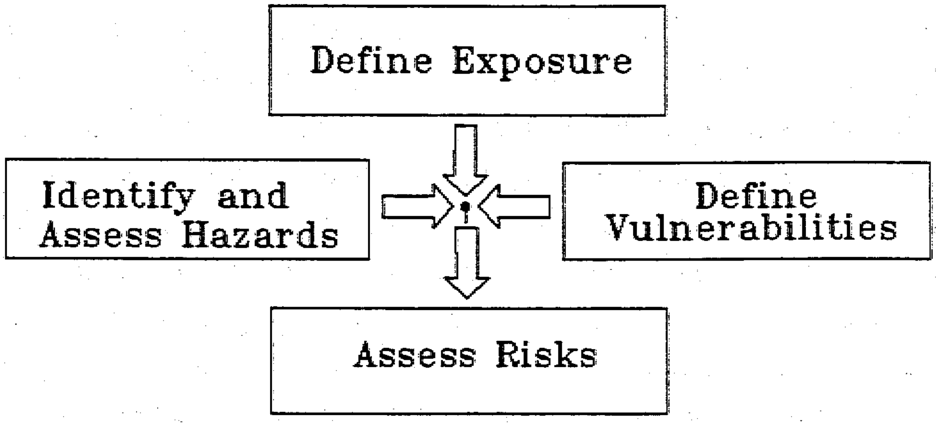


Figure 2-1. General Risk Analysis Approach

Exposure definition is an inventory process central to the collection of information for use in risk analysis. This involves use of a geographic system (e.g., longitude-latitude, Universal Transverse Mercator, State Plane Coordinates, township-and-ranges, zip codes) in order to identify facilities (e.g., buildings) and record other pertinent information such as facility descriptions, replacement cost estimates, building contents, number of occupants, and equity position.

Hazard identification and assessment involves examination of the natural sources and effects that give rise to risks (e.g., such potential natural hazard sources as floods, earthquakes, and hurricanes and such local hazards as liquefaction susceptible sites).

Vulnerability analysis determines the degree to which exposures (e.g., buildings, their contents, business operators, and people) are susceptible to damage as the result of specific hazard occurrances at various degrees of severity. A quantitative account of vulnerabilities, as of hazards, is needed in order to produce a quantitative assessment of risks.

Risk assessment takes into account identified exposures and their vulnerabilities to identified hazards.

These processes are often used individually as low-cost means to make specific decisions. This is very appropriate when other elements of the decision are known within reasonable bounds. For instance, the strong motion hazards to a building and its contents in Los Angeles may be known well enough to warrant recommendation of anchorage to critical equipment; however, a specific large-scale program of equipment anchorage needs to be guided by risk-reduction analysis methods.

Under most circumstances, however, used in isolation, the individual steps in the risk assessment process provide ineffective approaches to guide and monitor risk reduction programs. The identification of exposures by itself indicates little or nothing about the presence of hazards or the vulnerabilities involved. Hazard assessments by themselves indicate little about the vulnerabilities of various exposures or the types of exposures. Vulnerability assessment indicates little or nothing about the severities and likelihoods of the hazards or the values involved. Risk analysis methods are better suited to formulate, guide and monitor risk-reduction programs.

As suggested in Figure 2-1, when used in risk analysis, these basic processes of exposure definition, hazard identification and assessment, and vulnerability definition are not conducted independently or even sequentially. The exposure definition process must be closely tied to the other steps in the risk analysis process so that the hazards assessed and the vulnerabilities defined can be correlated with the facilities inventoried and the types of risk outputs desired (e.g., risks to schools versus risks to residential construction). Thus, the inventory process is central to the management of information that can be used in risk analysis, and contains elements that are neither hazards nor vulnerabilities.

Hazard identification and assessment becomes part of risk analysis and risk reduction efforts to the extent that (a) exposures are identified relative to hazards and (b) these exposures are determined to have vulnerabilities relative to the hazards. Quantitative risk estimates are possible only if hazards are defined so that the likelihood of the hazard occurrence can be assessed. For instance, identifying a region highly susceptible to landsliding is not enough to quantify risks. One needs to quantify the likelihood of landsliding either unconditionally or conditionally as a result of triggering events and then apply these probabilities to existing structures in the landslide area.

Risk analysis, then, employs the data accumulated through exposure definition, hazard identification and assessment, and vulnerability analysis to develop statistics that can be used to evaluate the extent to which specific exposures with their vulnerabilities are at risk to specific hazards. In the sense used here, risk assessment may terminate at the production of risk statistics or may involve a more complex procedure of assessing the significance of those statistics for risk evaluation and risk-control purposes.

Types of Seismic Risk Methods

Figure 2-2 summarizes types of risk methods available for analyzing LRMs and for earthquake rating purposes.

	DETERMINISTIC	PROBABILISTIC
SITE-SPECIFIC	Deterministic Site-Specific Methods	Probabilistic Site-Specific Methods
MULTI-SITE	Deterministic Multisite Methods	Probabilistic Multisite Methods

Figure 2-2. Types of Seismic Risk Methods

Deterministic methods are those in which "one or more earthquakes are postulated without explicit consideration of the probability that those events will occur" (NRC, 1989, p. 20). Often these postulated earthquakes are large, but deterministic methods may be used which postulate smaller magnitude events. (See Spangle, 1987; Algermissen et al., 1988.)

Probabilistic methods include probabilities for the entire suite of earthquakes potentially damaging an exposure or group of exposures.

Site-specific methods model each site as an independent exposure unit -- whether or not detailed geologic hazards and/or building vulnerability studies are performed.

Multisite methods model exposures (buildings) at two or more sites as potentially suffering losses from the same earthquake.

Examples of deterministic site-specific methods include analyses of the potential damageability of a specific building relative to a selected "response spectrum". Examples of deterministic multisite methods include many regional studies which have examined in detail the consequences of postulating selected, often large-magnitude earthquakes. (See Algermissen et al., 1973; Davis et al., 1982; Hopper et al., 1975; Algermissen et al., 1976; Algermissen et al., 1988; and Spangle, 1987.) Analyses of multiple sites which predict probable maximum losses (PMLs) are instances of deterministic multisite methods.

Examples of probabilistic site-specific methods typically estimate expected annual earthquake-related losses. These estimates of annual earthquake losses are used to calculate "pure premiums" -- premiums which do not include loadings for administrative, claims adjustment, and other costs and fees -- for earthquake insurance rating of annualized benefits of proposed LRMs. (See Liu and Neghabat, 1972; Wiggins et al., 1974; Whitman and Cornell, 1976; Whitman, 1975; Taylor and Ward, 1979; Petak and Atkisson, 1982; and Boissonnade and Shah, 1985.)

Examples of probabilistic multisite methods simulate a large number of potential earthquakes affecting facilities at diverse locations. (See Algermissen, Steinbrugge, and Lagorio, 1978; Taylor et al., 1985; Ostrom and Gould, 1986; and Taylor et al., 1990.) As we shall see in the following discussion, these models are most valuable for estimating extreme losses in the short term as well as overall annual expected losses. As a consequence, while more mathematically and computationally sophisticated than other methods, these can yield important information related to rates and to various types of benefits from proposed LRMs. Similar methods were used by Friedman and Roy to develop rates for the National Flood Insurance Program. (See Kaplan, 1971-72.)

Uncertainties in Risk Analysis in a Federal Insurance Context

Twenty years ago uncertainties in risk- and loss-estimation methods made the actuarial basis for an earthquake insurance rate-setting system very dubious (FIA, 1971). Methods for estimating seismic risk have advanced over the last twenty years, but significant uncertainties remain. We regard the discussion of suitability of methods (Section 2.2 as an example) as key to removing some major ambiguities or uncertainties.

As a consequence of considerable studies over the past two decades, the uncertainties in seismic risk analysis are no longer by themselves sufficient grounds for maintaining that earthquake perils are uninsurable. (For a much fuller discussion of the insurability issue see Butler et al., 1988.) Nevertheless, further advancements are needed if risk analysis is to meet the needs of a federal earthquake insurance program. In particular systematic efforts are needed to:

- o collect and publish post-earthquake loss data,
- o collect exposure data including building structure values and locations at risk,
- o assess probabilities of ground failures induced by liquefaction and landslides and to correlate to these phenomena both buildings and land values,
- o examine macroseismicity (seismicity on a regional basis and "rock" attenuation functions -- how seismic waves attenuate in amplitude as they pass through "rock").
- o examine the feasibility of microzonation for relative ground motion site response factors.

The relative importance of each of these types of information in risk analysis is a matter of some debate. Even though it has been maintained that regional seismicity factors are dominant in risk analyses, several different applications of seismic risk analyses have suggested that under some circumstances applications of loss models for diverse seismic construction classes may be dominant. (See Algermissen et al., 1988; Taylor et al., 1988.) Under other circumstances (e.g. the 1989 Loma Prieta earthquake and the 1985 Mexico City earthquake), relative site response factors become extremely critical. Hence, continued progress in macroseismicity studies is needed to remove uncertainties in seismicity and attenuation parameters, but other parameters cannot be ignored and should be investigated.

The need for systematic recovery and accumulation of earthquake loss data has been repeatedly emphasized throughout earthquake-related literature. (See NRC, 1989, and Wiggins and Taylor, 1986.) For application to a federal program, current institutional constraints on systematization and publication of existing loss data need to be overcome.

Since inventorying can be mundane, costly, and time-consuming, many investigators often fail to meet the critical need for systematic exposure data collection (NRC, 1989). Project workshop participants suggested that <u>inventory data be collected as properties are included in a federal insurance program</u>. Systematic development of basic exposure data on locations, values at risk, and general building structure types is critical for both primary and secondary federal earthquake insurance programs, since prospective liabilities in those programs cannot be assessed and effectively reduced without these data.

As suggested in this report, current weaknesses in scientific models estimating losses caused by permanent ground deformation make it difficult to assess the probable success of LRMs associated with potential ground failures. These include virtually all landuse LRMs. In order to improve the state-of-the-art in landuse planning for earthquake loss-reduction, it is necessary for planners also to begin to consider how to reduce the effects of high relative site response factors (the likelihood that a site will respond severely to an earthquake), which are potentially very high contributors to risk. This consideration may enter indirectly in seismic building code provisions as knowledge regarding site factors evolves along with microzonation identifying relative site response factors.

Linkages between Risk Analysis Methods, Loss-Reduction, and Insurance

When risk analysis (as defined above) is used as a tool in decision-making, the combined process is known as <u>risk and decision analysis</u>. As illustrated in Figure 2-3, risk and decision analysis is central to addressing the objectives of this project.

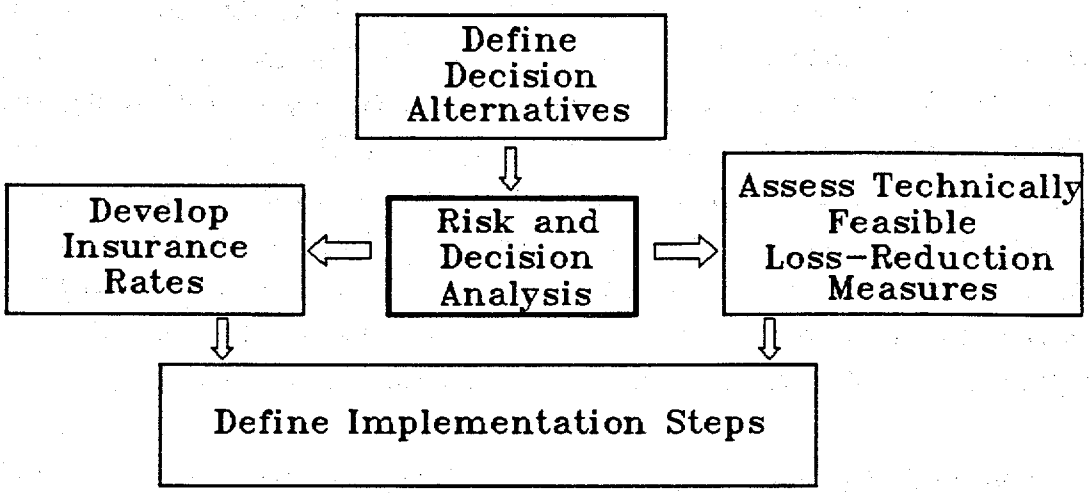


Figure 2-3. The Centrality of Risk and Decision Analysis in Linking Insurance and Loss-Reduction Measures

Decision alternatives considered in this project include incorporation of proposed LRMs in the following contexts:

- o the status quo (no major program changes),
- o federal government as primary insurer,
- o federal government as secondary insurer, and
- o federal government as both primary and secondary insurer.

In the assessment and selection of loss-reduction measures, risk and decision analysis methods assist in

- o estimating the aggregate benefits and costs of various proposed LRMs, and
- o estimating the benefits and costs to various key stakeholders.

Thus, these applications are very important in assuring that monies are directed toward those activities that have the greatest returns. Moreover, analysis of diverse stakeholder benefits and costs is useful for determining what types of existing and potential incentive systems (e.g., policy instruments such as subsidies and/or tax breaks) may be used to remove possible inequities and to incorporate cost-effective LRMs under the four decision alternatives. These applications are elaborated further in Sections 3 and 4 of this report.

Risk analysis methods are also required to develop insurance rates. Although rate determinations depend on a number of reserve development and cost considerations which are beyond the scope of this project, seismic risk analysis does play an important rôle in facilitating the relationship between insurance rates and LRMs. Some rate determinations can be counterproductive to instituting LRMs. From a broader perspective, risk analysis methods can be used as a tool to determine the trade-offs between costs of finer rate determinations and the benefits of loss-reduction. For instance, benefits of detailed mapping of poor site conditions and of establishing rate differentials based on site conditions can be compared to costs of developing and applying these rate differentials.

Successful implementation of insurance rating schemes and of proposed LRMs depends on how both factors together affect governments, individuals, and other types of stakeholders. For instance, federally subsidized rates may be desirable if the loss-reductions otherwise involved offset potential federal liabilities. For another instance, finer rate determinations may be desirable if the resulting rates induce implementation of loss-reduction measures and if the costs of these LRMs are not unduly borne by any of the individual stakeholders, including insurance companies, insurance regulators, and the general taxpayer. Implementation also requires monitoring of programs. Risk and decision analysis methods are needed both to predict and to evaluate the success of implementation of proposed rating schemes and loss-control measures.

In summary, risk and decision analysis methods serve as important tools in examining insurance rate-setting and LRMs within the context of a federal program. Nevertheless, the risk analysis procedures that we have been discussing are primarily directed toward specific actuarial, professional, economic, and technical considerations, with relevance to other factors. For the purposes of this study, a broader approach which incorporates an even wider range of considerations was needed. The STAPLE (social, technical, administrative, political, legal, economic -- but also, as H. Kunreuther has indicated -- actuarial, procedural, ethical, environmental, professional, and so on) approach discussed by Petak (1981) was used to ensure consideration of all relevant issues. The further application of risk and decision analysis methods to the selection of cost-effective LRMs is a major concern of Section 3 of this report. The variety of additional considerations such as political costs and legal constraints that are involved in assessing diverse decision alternatives is considered in Section 4 of this report. Their application to insurance rate-setting is discussed in Section 5.

Recommended Uses of Risk Analysis

Based on the foregoing considerations and on the project workshop, the following uses of risk analysis are highly recommended:

- o providing the basis for benefit-cost analysis in order to determine the suitability of building practice LRMs for inclusion in a federal program;
- o providing nationwide estimates of losses and casualties and of reduced losses through implementation of specific measures;
- o providing estimates for monitoring and modifying loss-reduction programs undertaken;
- o providing a basis for developing premiums, deductibles, and limits of liability for an earthquake insurance program;
- o providing a basis for proposed zoning schemes (macrozonation and/or microzonation) to be used in a federal program;
- o clarifying the degree to which one should place confidence in seismic loss estimates and perhaps improving the reliability of these estimates;
- o clarifying those parameters which contribute most to the uncertainty in seismic loss estimates and suggesting various approaches to reducing this uncertainty.

Although rated less highly in the project workshop, the following uses also deserve consideration:

- o providing estimates that serve as a basis for examining potential derivative losses to different sectors of the economy (the stakeholder analysis in Section 4 is an example of this method);
- o examining in greater depth the earthquake damageability of critical or essential facilities and determining the most cost-effective means of reducing this earthquake damage (see especially Section 3.3);
- o providing a basis for estimating the cost-effectiveness of various landuse programs such as specific programs designed to reduce seismically-induced landslide losses (see Section 3); and
- o providing a basis for estimating time-varying reserves and subsidy levels within the context of an earthquake insurance program (see Section 2.2).

2.2 The Use of Risk Analysis in Insurance Rating Methods

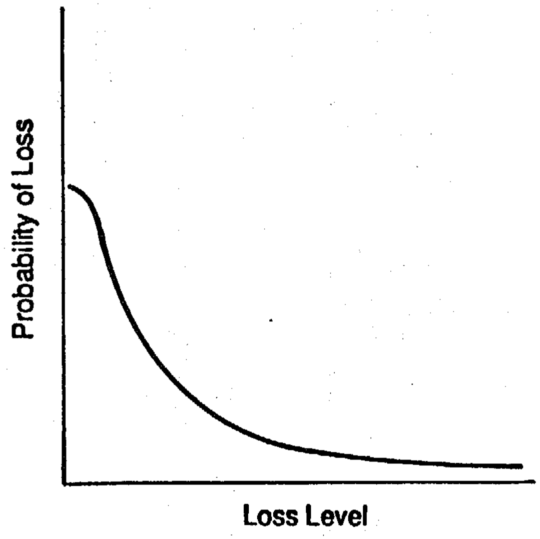
In this section we examine the application of risk analysis methods to evaluating insurance rates under different federal involvements in earthquake insurance.

Risk Analysis Methods Suitable for Use by Private Insurers

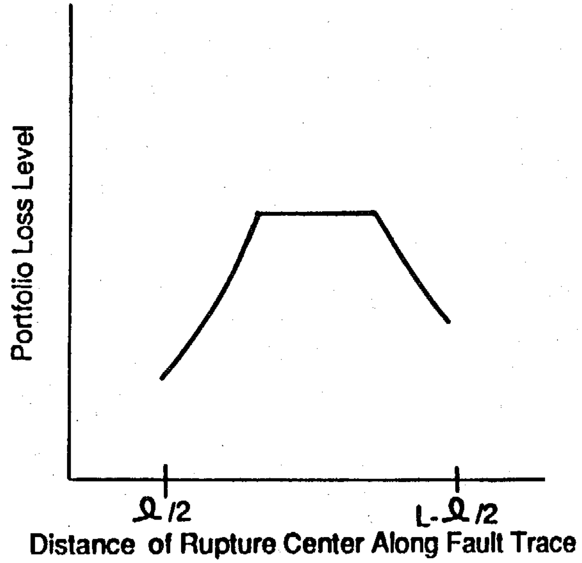
Eguchi et al. (1989) and Taylor, Hayne, and Tillman (1990), have maintained that for private insurers (and reinsurers) probabilistic multisite methods (variants of ruin analyses used in actuarial science to ensure that insurance companies do not face high risks of insolvency) are most suitable for defining insurance rates (premiums, deductibles, and limits of liability). Succinctly put, they argue mathematically that:

- o Probabilistic site-specific methods, which develop rates based on expected annual losses (as in Boissonnade and Shah, 1985), fail to take into account extreme short-term fluctuations in earthquake losses. These extreme short-term fluctuations can lead to insurer and/or reinsurer insolvencies which in turn harm consumers and more prudent insurers/reinsurers.
- o Deterministic multisite methods, such as "probable maximum loss" (PML) methods in Anderson, 1981, add some information regarding possible extreme events. But these PML methods do not by themselves necessarily cover expected losses, and the ratio of PML to expected annual loss varies too extremely -- by a factor of twenty across different regions of the United States -- for PML to be an equitable basis for rate-setting. Indeed, adverse selection may be encouraged by a PML rating method inasmuch as higher risks have lower ratios of PML divided by expected annual loss. The information provided by these PML methods, even with respect to extreme events posing short-term solvency concerns, can be made much more coherent through probabilistic methods.
- o Products of probabilistic multisite methods (see Figure 2-4 for examples) can be used to determine rates relative both to short-term fluctuations (the catastrophic element needed to assure that contractual obligations with consumers are fulfilled) and the expected loss element (needed to cover costs). (Taylor et al., 1985, justify the use of 2-4(b), a model better known for application to individual sites, for application to multiple sites.)

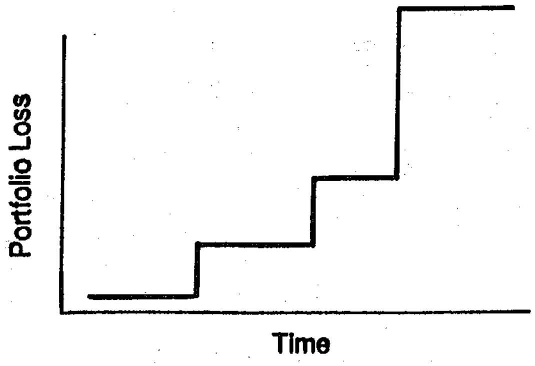
Thus, it can be concluded that <u>private insurers (status quo) currently benefit from probabilistic multisite methods, which incorporate expected annual loss and catastrophic loss potential into a coherent framework</u>.



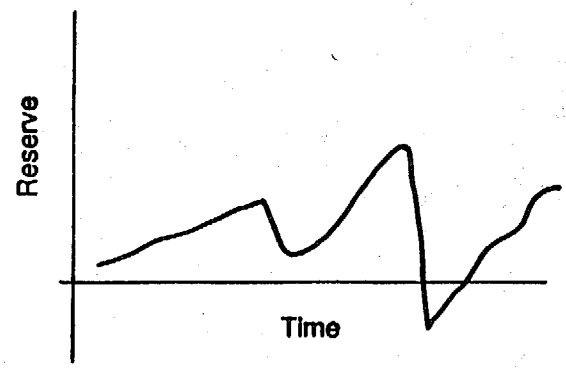
(a) Illustrative Probabillity of Loss as a Function of Loss Level Output



(b) Illustrative Loss Levels for a Portfolio Relative to a Specific Fault Trace and Magnitude of Interest (L is Total Fault Length; ℓ is Rupture Length)



(c) Illustrative Simulation of Portfolio Losses Over Time



(d) Illustrative Simulation of Effect of Portfolio Losses on Reserve

Figure 2-4. Illustrative Probabilistic Multisite Analysis Outputs

Risk Analysis Methods Suitable for Use with Federal Insurance

With direct federal involvement in earthquake insurance, the above conclusions may need to be revised in view of public policy considerations required to guide actuarial rate assessment work. Public policy analysis is needed to determine which of the following will guide actuarial analysis:

- o The net reserve is positive trending (premium income exceeds expected program costs including expected earthquake losses).
- o The net reserve is zero.
- o The net reserve is negative-trending (a subsidy situation).

Moreover, public policy analysis is needed to assure that short-term potentially extreme fluctuations in losses can be handled within the political system (e.g., that these extreme fluctuations will not create extreme program instabilities). In addition, detailed public policy and economic analysis would be needed to assess possible regressive or progressive effects of various rate structures such as effects of specific proposed rate structures on low-income citizens. (No systematically documented work on this subject is known to the project director.)

Obviously, public policy evaluation of these topics will depend on the type of federal insurance involvement considered (as a primary insurer, as a secondary insurer, as a "banker" of last resort) and the distribution of and types of properties covered. A mandated program, with monopolistic implications, will differ from a voluntary program. A residential program will differ from a commercial program.

With respect to a **mandatory primary** federal earthquake insurance involvement (as for selected classes of buildings) expected annual loss (probabilistic site-specific) methods may suffice in order to develop crude approximations for earthquake insurance rates. As explained in Eguchi et al. (1989), although these expected loss methods contain important uncertainties and are often performed incorrectly, they include advantages derived from many developments originally designed for the building code and nuclear power plant industries. (See Algermissen, 1983; Bender and Perkins, 1987; McGuire et al., 1988.) Probabilistic multisite methods are helpful in studying extreme short-term loss fluctuations which may be significant in a mandated primary program, but such results will be less important for required programs than for voluntary programs.

In **voluntary primary** programs, problems of adverse selection can easily arise if insurance rates do not adequately reflect risk levels. This is particularly the case when the insured knows more about his risk than the insurer. Cases of adverse selection may involve individual exposures, such as when the insured is in a highly risky location and the insured building is more vulnerable than the "typical" building used for rate-setting. Cases of "adverse selection" in a broader sense may also involve aggregate (more than one) exposures, such as when many property owners in one small seismic region purchase insurance and so create a catastrophic loss potential that has not been anticipated fully in rates. Problems of adverse selection are reduced to the extent that rates reflect risk. Nevertheless, the "adverse selection" or unanticipated catastrophic element involving aggregate exposures still poses problems for a voluntary program. To anticipate this latter problem, probabilistic multisite methods are most useful in rate development for voluntary primary federal insurance programs.

Secondary federal earthquake insurance involvements will typically require examination of higher earthquake loss potentials. Hence, in the typical case, the suitable methods to be used will be those that consider the extreme tails of the distribution suggested in Figure 2-4(a). Expected annual federal liabilities can be calculated from such a distribution, and so can be used along with administrative and other cost factors to estimate expected aggregate prices for federal involvement. Thus, probabilistic multisite methods are desirable for assessing potential federal liabilities (if any) in a secondary federal program.

In order to apply these methods, one critical factor will be inclusion of inventory data on

- o values at risk,
- o locations, and
- o general types of structures.

Although inventory problems can be severe, and aggregation methods will be needed (e.g., to estimate exposures by zip code or by county), workshop participants suggested that these inventories can be developed at the time of purchase. This proposal appears to apply best to a primary earthquake insurance program. Development of exposure data to support risk analysis in support of a secondary program presents a formidable task, given the obstacles that currently exist to systematic recording and transfer of exposure data within the insurance and reinsurance industries. (See Section 5 for information on a secondary federal earthquake insurance program.) Also essential to the implementation of these methods are

- o use of earthquake source zones (and further examination of sensitivities of rates developed to alternative selections of source zones),
- o use of "rock" attenuation functions for different regions of the country, and
- o use of soft soil factors (whether to microzone or merely to assess more accurately overall potential federal liabilities).

The first two factors have been well developed in procedures for model building code organizations and the nuclear power industry. The third factor is included by the project director on the grounds that soft soil site dynamic amplification factors have contributed significantly to the degree of damage resulting from varying shaking intensities in many past earthquakes (see Hays, 1980, 1981). In regions of very low seismicity, sensitivity analyses may be used to determine whether or not rates would fluctuate significantly should these soil factors be included. In regions of higher seismicity (certainly zones 3 and 4) microzonation of soft soils is needed to determine aggregate earthquake loss potential within these zones.

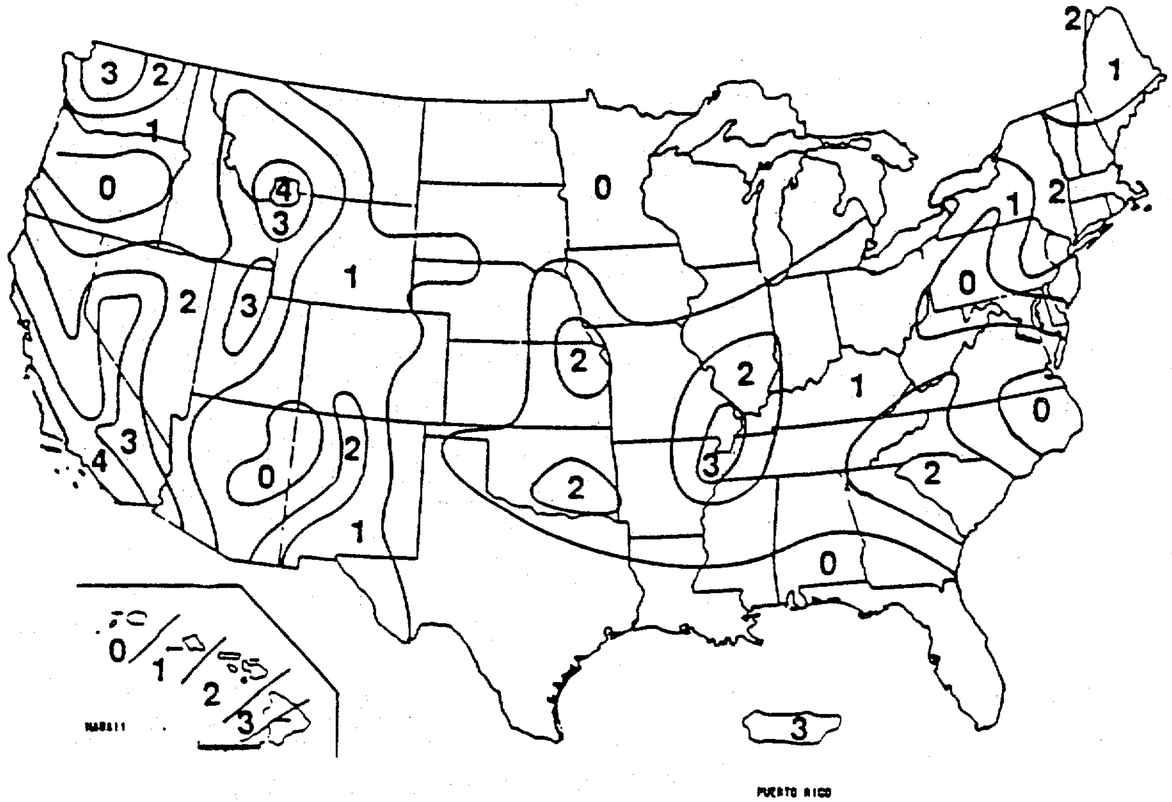
In summary, deterministic methods, including probable maximum loss (PML) approaches, have extremely limited utility for both socioeconomic evaluations of LRMs and earthquake insurance rate-setting. For most earthquake insurance rating purposes, probabilistic multisite methods are appropriate. Under a mandatory primary national program, probabilistic site-specific methods may be adequate for basic rate-making, even though multisite methods would be desirable to assess short-term expense fluctuations in losses. Further applications of these approaches are discussed in Section 5.

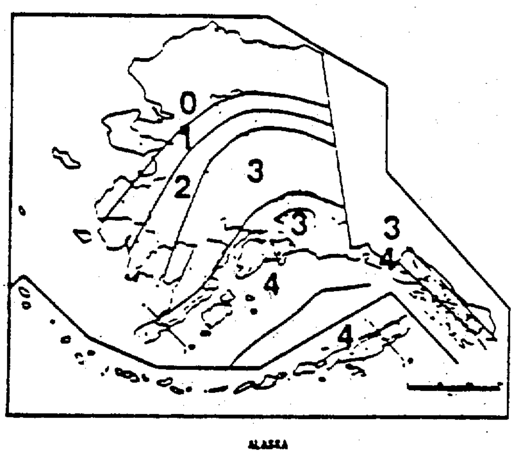
2.3 Mapping Considerations

In this section, we discuss briefly mapping considerations in a federal earthquake insurance program involving LRMs. We first discuss the sorts of small-scale maps used for building codes. Next, we discuss generally larger scale maps for LRMs. Third, we discuss how rating maps could diverge significantly from maps for LRMs. We maintain that the administrative difficulties of employing two widely divergent sets of maps, one for LRMs and another for rating, provides a strong reason for developing to the extent possible a single set of maps for both LRMs and rating.

Seismic Zone Maps

Figure 2-5 is an adaptation of one small-scale consensus seismic zone map. The original map uses probabilistically derived contours of strong ground motion values (in this





* EXPLANATION

For Adapting Figure C-1, We Have Used the Following Relationships Between Seismic Zones and Peak Horizontal Ground Accelerations:

Seismic Zone	Peak Ground Acceleration (Percentage of Gravity)	Shaking Hazard Level
0	< 0.05	Lowest
1	≥ 0.05 and < 0.1	↓
2	≥ 0.1 and < 0.2	
3	≥ 0.2 and <0.4	
4	≥ 0.4	Highest

Figure 2-5. Illustrative Seismic Zone Map for the United States

(Adapted from "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings," FEMA Publication 18 by the Building Seismic Safety Advisory Council, 1988) case, peak ground acceleration values derived by conversion from peak ground velocity values). Scientifically derived contours are subjected to a consensus process that assures consideration of a wide variety of scientific, engineering, and building construction practices within the contours produced. These consensus maps are designed primarily for uses in design and in construction and in the development of seismic building codes. The adaptation in this report has resulted in seismic zone designations 0, 1, 2, 3, and 4. The resulting map in Figure 2-5 differs from other seismic zone maps. For instance, seismic zone designations in the 1988 edition of the Uniform Building Code will be higher in Oregon, portions of Alaska, California, and other states west of the Rocky Mountains. Since we do not urge modifications of the seismic provisions of the Uniform Building Code, Figure 2-5 can serve as a minimum initial basis for the LRMs proposed in this report. However, in a federal earthquake insurance program, development of consensus seismic maps will be a first priority both for insurance rating and LRMs.

From the standpoint of science and engineering, the basis for such maps has evolved significantly over the past twenty years, especially as a result of the national hazard mapping program and also as a result of special studies of major sites and facilities. Continued research (see Whitman, 1989) is ongoing in an attempt

- o to combine geological and historic earthquake data,
- o to estimate "rock" attenuation patterns, and
- o to estimate effects of soft soils and special geologic configurations in amplifying the effects of strong ground motions.

In regions with limited seismicity, or where historic seismicity may not be an adequate clue to expected seismicity, estimates of seismicity may vary, and these may lead to large variations in loss estimates. Thus, in the administration of a federal earthquake insurance program, updates of seismic hazard information and loss estimates will be needed periodically as scientific and engineering knowledge grows. Also, it should be noted that the effects of these variations on proposed rates may be as significant in moderate-to-high seismic zones (zones 3 and 4) as they are in lower seismic zones. In lower seismic zones, costs of underwriting can become a significant consideration in rate development; that is, given the low expected annual losses estimated in these regions, minimum rates may be required merely to cover costs of writing the insurance.

In using such maps, administrators must be aware of the constant possible progress in refining such maps. Specifically, incorporation of soft soil site dynamic amplification factors into such maps is imminent. (See Whitman, 1989.) In the near term, new seismic maps are expected to be developed that reflect

- o additional studies of seismicity, including studies of the eastern U.S., and
- o relative site-response factors critical in assessing potential losses.

As a result, federal officials should be aware that seismic maps are constantly being augmented and that refinements in the next few years likely will be more consistent with the LRMs proposed in this report. While all such new maps developed undergo consensus processes which in many cases may take decades to implement into building and landuse practices, they should be readily available for use in implementing LRMs and evaluating insurance risks.

Mapping Local Hazards

Although relative site response factors are becoming integral to seismic zone maps for building codes, and although this information is critical to estimating losses (as discussed in Section 2.1 and Eguchi et al., 1989), the use of ground failure potential maps for purposes of local loss-reduction is far more ambiguous. While techniques are currently available for delineating surface fault rupture, landslide, liquefaction, and subsidence local hazards, ambiguity results from

- o the lack of data with which to estimate losses associated with various types of ground failures (except in clear cases such as when total constructive loss would be expected), and
- o the lack of convincing methods to calculate on a regional basis the probability of ground failure or its severity.

As an example, with respect to liquefaction zones, it is currently not known how much potential ground deformation can be expected given earthquake magnitudes of less than 6.5. (See Taylor et al., 1988.) Yet, since occurrences of magnitudes below 6.5 are far more likely than those above 6.5, the contribution of these lower magnitude levels to expected losses is very great. (See Taylor, Atkisson, and Petak, 1981.) Likewise, seismic risks from landslides have not been examined thoroughly. Furthermore, mapping on a local level appears to be expensive. We recommend investigations to develop economical mapping procedures before any large-scale mapping program is initiated. Validation of the assumption that old landslides serve as good indicators of potential earthquake-induced landslides could, for instance, produce economic means for mapping potential earthquake-induced landslides.

In spite of these caveats, it is clear that permanent ground failures do cause losses and that there are clear-cut cases of very high potential for such ground failures. Adverse selection can result if these local hazards are ignored in insurance rate-making. Hence, in Section 4, we maintain a pragmatic attitude toward these hazards, and recommend initial compilation of existing sources of information and an intermediate scale (not larger than 1:24,000) mapping program only in high risk seismic zones (3 and 4). These supporting activities are modest in cost given projects already completed through the United States Geological Survey and through state and local programs. Review of findings on probabilities and potential extent of these hazards, and also on losses associated with these hazards, will assist in later program developments.

Mapping and Insurance Rating

An earthquake insurance program could be designed in ways in which maps for LRMs diverge somewhat significantly from maps that provide insurance "rating zones." Unlike the National Flood Insurance Program, which begins with large-scale maps and integrates them into the insurance rating process, an earthquake insurance program may begin with small-scale maps. Public policy considerations must be addressed before maps for earthquake insurance rating can be developed.

For instance, chiefly for political, jurisdictional, or administrative reasons, it may be decided that rates should be developed relative to political boundaries that do not cross-subsidize each other. If probabilistic multisite approaches are used, then the catastrophic loss potential in a given territory will have significant impact on how rates are developed.

Moreover, key decisions affecting rate-setting in a federal insurance program will pertain to

- how detailed the microzonation should be for rate development,
- how detailed the seismic building vulnerabilities should be (what proxies may be used to estimate roughly these vulnerabilities, which may be very great for the large majority of buildings in the United States, especially older buildings or buildings located east of the Rockies), and
- whether a subsidy situation, a net zero financial gain, or a surplus reserve is desirable.

Before such issues are addressed, it is unclear what insurance rating maps should look like. For instance, if seismic building vulnerabilities vary from region to region, then contours of expected or average annual losses (so-called pure premiums, or premiums without catastrophic loadings -- the terminology varies among actuaries) will not necessarily be identical with contours of probabilistic peak strong ground motion values. If political boundaries are used with different catastrophic loadings for different territories, then contours of basic premiums (pure premiums loaded to account for catastrophic occurrences) may differ from contours for expected annual losses. Moreover smoothing techniques may be used that produce jurisdictional rating maps rather than maps based primarily on loss potential. Hence, mapping for earthquake insurance rating purposes will not necessarily mirror mapping for LRMs.

Various administrative pitfalls occur if maps for LRMs diverge too greatly from maps for insurance rating. The first is internal -- the program would involve separate functions, each producing maps of a very different sort and hence not working on a common basis. Use of a risk basis for maps would avoid this internal administrative problem. The second is external -- it would become readily apparent to the public-at-large and to their representatives that maps for rating did not correspond to maps for LRMs. Hence, for administrative simplicity, maps for LRMs should correspond as closely as possible to maps for rates. We later conclude that to encourage cost-effective LRMs, partially risk-based rates are desirable. A risk basis for both LRM maps and rating maps would offer a further very large administrative advantage.

2.4 Conclusions

In this section we conclude that:

- o Although uncertainties still characterize seismic risk analysis methods, these uncertainties have been significantly reduced through many studies over the past two decades so that seismic risk methods are now acceptable for use in a national earthquake insurance program.

- o Deterministic methods including probable maximum loss (PML) approaches have extremely limited utility in either socioeconomic evaluations of LRMs or earthquake insurance rating. For most earthquake insurance rating purposes, probabilistic multisite methods are appropriate. Under a mandatory national program, site-specific probabilistic methods may be adequate for basic rate-making even though multisite methods would be desirable to assess short-term fluctuations in losses.

- o Small scale seismic zone maps at a national or regional scale are critical to the implementation of LRMs. Various theoretical and practical limitations exist to large-scale micozonation mapping, but these may soon be largely overcome through research targeted to resolving issues related to assessing probabilities of permanent ground displacements. Severe administrative disadvantages occur if maps for LRMs, especially at a small scale, diverge too significantly from maps for rating.

3.0 THE IDENTIFICATION, DEVELOPMENT AND ECONOMIC EVALUATION OF PROMISING LOSS-REDUCTION MEASURES

The primary objective of this project is to identify feasible alternative earthquake loss-reduction provisions and develop a strategy to FEMA for incorporation of recommended loss-reduction provisions into a national earthquake insurance or reinsurance program.

In order to achieve this two-part goal it was necessary first to identify earthquake loss-reduction provisions for recommendation. To be recommended, a loss-reduction measure must be technically sound, cost-effective, and otherwise acceptable to a wide variety of individuals who will be affected by the measure.

This section reviews the procedures used to accomplish this task and presents the results of efforts to identify and develop cost-effective loss-reduction measures (LRMs) which could serve as loss-reduction provisions within the context of a national insurance or reinsurance program. Specifically,

3.1 summarizes the process used to identify feasible earthquake loss-reduction provisions.

3.2 reviews the results of efforts to identify hazard reduction activities for candidacy as feasible loss-reduction measures (LRMs).

3.3 reports the findings of socioeconomic analyses conducted to determine whether or not these candidates could be considered cost-effective.

Section 4 summarizes the process used to evaluate the "acceptability" of these measures, presents the resulting set of feasible loss-reduction measures (LRMs) and necessary supporting activities, and reviews issues of acceptability as discussed during the course of this study.

Throughout this process the STAPLE (Social, Technical, Administrative, Political, Legal, Economic) approach was utilized to ensure that (a) a wide range of available earthquake hazard reduction activities was considered and (b) the LRMs developed were analyzed and evaluated from all necessary perspectives.

Section 5 will sort out the various ways in which cost-effective LRMs or earthquake ordinances may fit into various types of federal involvements.

3.1 The Process of LRM Identification and Evaluation

In order to achieve the primary objective of this study, a significant effort was directed toward identifying, defining, and assessing possible loss-reduction provisions appropriate for inclusion in a national program for earthquake insurance or reinsurance. The steps used in this process are illustrated in Figure 3-1.

1. Identify earthquake hazard reduction activities through a thorough information search.

⇩

2. Select and restate a smaller number to be subjected to more thorough analysis

⇩

3. Analyze these activities on socioeconomic grounds

⇩

4. Present initial results at a Project Workshop for final development of LRMs and further analysis by knowledgable and interested parties.

⇩

5. Present results for future analysis at the final Advisory Panel meeting and to other reviewers of draft final reports.

Figure 3-1. Steps Used to Develop and Assess Recommended Loss-Reduction Measures

1. Conduct a thorough information search to identify hazard reduction activities which could be used as components of a loss-reduction program. The very thorough information search was designed to assure that a wide variety of sources was considered from the growing literature on earthquake loss-reduction. Additionally, the <u>very thoroughness</u> of the information search was designed to provide a resource for future efforts to re-examine possible efforts. This search produced a collection of ninety-six earthquake hazard reduction activities for consideration.

2. Reduce the number of possible earthquake hazard reduction measures and restate them as needed so as to facilitate analysis and further development. In the second stage of this process, the project team used expert judgment to select, synthesize, and restate hazard reduction activities as a smaller number of more technically feasible loss-reduction provisions.

3. Perform socioeconomic risk-and-decision analyses of the technically feasible loss-reduction activities. Questions of practicality were of utmost importance in the third step of the process. In this step the technically feasible loss-reduction activities developed in Step 2 were subjected to socioeconomic analyses in order to determine their level of cost-effectiveness (economic efficiency) and their economic impact on various stakeholders (economic allocation).

4. Present the preliminary results of technically and economically feasible loss-reduction activities at a Project Workshop for further revision, refinement, and definition as loss-reduction provisions within the context of a national earthquake insurance program. Once the list of possible loss-reduction activities had been limited to those identified as cost-effective, they were synthesized and restated. A report of this work was generated and sent to Project Workshop participants (knowledgeable individuals representing a variety of stakeholder interests). At the Workshop, participants were asked to review and critique the socioeconomic analyses and then re-examine, refine, and augment the candidate loss-reduction measures in the light of their various interests. The collection of promising loss-reduction activities was condensed and synthesized into fifteen Loss Reduction Measures (LRMs) with corresponding Supporting Elements. Discussions evaluating the acceptability of these measures from the perspectives of various stakeholders addressed risk analysis, insurance, and public policy issues.

5. Present initially recommended loss-reduction measures at a final advisory panel meeting and in two final draft reports for further review and revision. Workshop findings resulting in fifteen initially recommended LRMs were developed in a preliminary final draft report and presented at the third advisory panel meeting for review. A final draft report was also submitted for review by advisory panel members. This process resulted in restatement and elaboration of many of the LRMs to make them more acceptable in the light of objections raised.

The remainder of this section discusses in further detail each of the processes used to identify technically feasible loss-reduction measures and to evaluate these technically feasible LRMs on the basis of cost-effectiveness.

3.2 The Identification and Selection of Technically Feasible LRMs

Information Search

As a starting point for accomplishing the tasks required by this project, a comprehensive search of earthquake-related information was conducted to identify earthquake hazard reduction activities which could satisfy the definition of loss-reduction measure as an activity involving a physical intervention or restraint thereon that reduces expected building losses associated with earthquakes. In order to assure thoroughness we developed a data collection and evaluation (DACE) instrument through which each activity was characterized by five descriptors. These could later be used to sort and review results to assure that all aspects of the descriptor had been considered in the course of the search. Thus, each hazard reduction activity was characterized by:

- a general description of the earthquake hazard reduction activity in terms of (a) a physical description of the "fix", which qualifies the activity to be considered as a possible LRM as defined in section 1.3, (b) specification of the activities necessary to support the LRM (e.g., maps, building inventories), and (c) identification of the methods needed to verify implementation (e.g., engineer sign-off, random sampling techniques, risk analyses, public policy analyses),
- the source document(s) used to identify and develop the earthquake hazard reduction activities, including
  - library searches [in-house Dames & Moore; Natural Hazards Research and Applications Information Center (NHRAIC) in Boulder, Colorado; the National Center for Earthquake Engineering Research (NCEER) Information Service in Buffalo, N.Y.; and the Earthquake Engineering Research Center (EERC) Library at Richmond, California],
  - legislative, bibliographic, and other materials developed from a number of other federal, state and local sources suggested by the advisory panel and those listed in the acknowledgments, and
  - reports from projects previously developed by project team members and advisory panel members.
- general type of application (e.g., landuse and building practices; residential, commercial, and critical public building usages) to assure that all applications required by the project (see section 1.3) were addressed,
- type of structure affected to assure that all main building types were covered, and
- region of application as defined by seismic zone, to assure that all regions of the country were covered,

Ninety-six earthquake hazard reduction activities were identified and stated in great detail. A full report of these findings would be useful for those interested in re-examining a broader range of possible loss-reduction activities. Their importance to this project was primarily to ensure a thorough preliminary basis from which promising loss-reduction measures and their supporting elements could be identified, systhesized, and developed. As a result, they are not included in this report. The remainder of this section reports the results of this process.

Application of Engineering, Scientific, and Risk Criteria to Identify Possible Loss-Reduction Activities

In the next step, the project team used expert judgment in order to produce a shorter list of possible loss-reduction measures that could be subjected to a risk-and-decision analysis. In many cases, the information search identified overlapping activities that could be synthesized into a fewer number of possible loss-reduction measures. In other cases, activities were eliminated for one of many possible reasons, including

- o lack of technical feasibility (as determined, for instance, through the judgment of geotechnical and structural engineers on the project),
- o obvious lack of political feasibility,
- o narrowness of application relative to a national risk-reduction or insurance program (e.g., the activity applied to a limited number of buildings or in such rare circumstances that state and local administrators would tend to ignore them),
- o imprecision of pertinent technical description (e.g., administrators would not know how to implement the earthquake hazard reduction activity),
- o absence of technical evidence that losses would significantly be reduced through the implementation of the putative hazard reduction activity (e.g., for existing steel-frame buildings, technically possible seismic retrofits may not improve seismic performance significantly), and
- o obvious lack of cost-effectiveness (e.g., practitioners currently do not use this measure because more cost-effective techniques are available).

Once a shorter list of activities was produced, these activities were restated in order to facilitate socioeconomic analysis. Candidate activities naturally fell into two groupings -- **Landuse Measures** and **Building Practices**. Under landuse measures we included various practices, such as site preparation, to minimize or avoid geological hazards. Under building practices we included various measures to modify the building structure through design or redesign. This distinction between landuse measures and building practices is well-recognized in different bureaucratic and professional functions, with site preparation activities forming one link between the two types of activities. In section 5 we use the expression "earthquake ordinances" in order to facilitate greater administrative linkage between landuse measures and building practices.

The following two subsections present, respectively, the landuse measures and building practices that were subjected to socioeconomic analysis.

Landuse Measures

Table 3-1 lists the candidate loss-reduction measures related to landuse practices that were submitted to socioeconomic analyses. Seismic zones specified in these tables are illustrated in Figure 2-5. Landuse measures generally involve policies, ordinances, and legislation regulating three classifications of landuse planning:

- o regulation of new development of sites,
- o removal/conversion of existing structures and sites, and
- o use of appropriate engineering and construction measures to mitigate damage for both new and existing developments.

Policies, ordinances, and legislation to be applied to **new development** include

- o development of public information and notification programs to place developers, realtors, and purchasers on notice of existing hazards;
- o discouragement of development in potentially hazardous (e.g., poor soil and/or ground-failure prone) areas by means of disclosure and/or such financial mechanisms as disallowance of tax deductibles after losses or special local taxes;
- o regulation of new development through subdivision regulations, grading ordinances, hillside-development regulations, and other zoning specifications;
- o state legislation related to liquefaction and landslide hazards similar to the 1972 Alquist-Priolo Special Studies Zones Act[1], which covered surface faulting.

Policies, ordinances, and legislation regulating removal/conversion of **existing development** should ensure

- o acquisition, exchange, and relocation of properties in high hazard locations (e.g., high liquefaction susceptible sites),
- o discontinuance of non-conforming land uses,
- o removal of unsafe structures through public nuisance abatement powers,
- o use of a non-conforming building ordinance requiring eventual removal of structures in the greatest danger, and
- o post-disaster redevelopment.

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1. California Senate Bill 520 (1972), the Alquist-Priolo Geologic Hazard Zones Act, requires the State Mining and Geology Board to prepare policies and criteria for the development of areas encompassing major active fault traces, which are to be mapped by the state geologist. It was amended in 1975 to require disclosure to prospective buyers (see Palm, 1981).

Table 3-1

Landuse Measures Analyzed

Number	Brief Description
1000	Purchase (if needed) existing construction or properties in very active fault zones of deformation (hence in seismic zone 4) and convert to low-density purposes or open space only. (The expression "very active" is defined operationally in Appendix B.)
1100	Purchase (if needed) existing construction or properties in moderately active fault zones of deformation and convert to low-density usage or open space only. (The expression "moderately active" is defined operationally in Appendix B.)
1200	Restrict new development in very active fault zones of deformation (in seismic zone 4) to low-rise residential construction. (Assume that residences and other construction would be designed to seismic code.)
1300	Restrict new development in moderately active fault zones of deformation in seismic zone 4 to low-rise residential construction. (Assume that residences and other construction would be designed to code.)
1400	Restrict new development in moderately active fault zones of deformation in seismic zone 3 to low-rise residential construction. (Assume that residences and other construction would be designed to code.)
1500	In seismic zone 4 as deemed appropriate by geotechnical engineers prior to development, drive piles, use vibro-compaction, or use dynamic deep compaction in order to minimize potential ground failures owing to liquefaction. (Assume that seismic codes are adopted and enforced.)
1600	In seismic zone 3 as deemed appropriate by geotechnical engineers prior to development, drive piles, use vibro-compaction, or use dynamic deep compaction in order to minimize ground failures owing to liquefaction. (Assume that seismic codes are adopted and enforced.)
1700	In seismic zone 4 restrict new development in very susceptible liquefaction zones to low-rise residential structures.
1800	In seismic zone 3 restrict new development in very susceptible liquefaction zones to low-rise residential structures.
1900	In seismic zone 4 allow major modifications of existing structures in very susceptible liquefaction zones only for which suitable geotechnical techniques can be used to minimize hazards resulting from ground failures.
2000	In seismic zone 3 allow major modifications of existing structures in very susceptible liquefaction zones only for which suitable geotechnical techniques are used to minimize hazards resulting from ground failures.
2100	In seismic zone 4, in very susceptible landslide locales, restrict new development to open-space uses.
2200	In seismic zone 3, in landslide locales, restrict new development to open-space uses.
2300	In seismic zone 4 purchase (if necessary) land and/or severely damaged construction and convert existing development in very susceptible landslide locales to open-space uses.
2400	In seismic zone 3 purchase (if necessary) land and/or severely damaged construction and convert existing development in very susceptible landslide locales to open-space uses

Policies, ordinances, and legislation regulating **engineering and construction measures** used to mitigate damage should include

- o measures to protect existing development from damage in landslide areas, including measures for slide and slump control, mud- and debris-flow control, and rockfall control; and
- o measures to protect existing development in high liquefaction susceptible areas including nonstructural solutions, improving the soil in-place, and changing the project structure.

Few very active fault zones of deformation exist in the United States. For operational purposes, we have defined these as having surface expression at any site along the fault every five hundred years or less. Chief examples of these very active fault systems include the San Andreas, Hayward, and San Jacinto fault systems, but not the Wasatch or Newport-Inglewood fault systems. "Blind" thrust fault systems, such as generated the 1987 Whittier Narrows earthquake, and offshore fault systems are excluded from consideration inasmuch as they do not generate surface faulting hazards. For very susceptible liquefaction, landslide, or settlement zones, we refer to such zones as Turnagain Heights in Anchorage, the Marina District in San Francisco, sites adjacent to the Duwamish River in the Puget Sound, sites adjacent to the Jordan River or Great Salt Lake in the Wasatch Front region, and similarly severe landslide zones. The emphasis of this report is toward site preparation and/or avoidance of "severe" ground failure susceptibilities since current evidence does not suggest large risks in zones with moderately susceptible ground failure hazards. At the same time, risks of building losses from strong ground motion are emphasized in this report. This emphasis is not merely presupposed, but also is tested in terms of the cost-effectiveness analysis in this section (with greater detail in Appendix B).

Building Practices Resulting in Loss Reduction

Table 3-2 lists the candidate activities related to building practices that were submitted to socioeconomic analyses. Again, seismic zones specified in these tables are illustrated in Figure 2-5.

In describing building practices that augment current efforts toward loss-reduction, we have assumed that <u>for the most part</u> adequate seismic building codes are in effect in seismic zones 3 and 4 west of the Rocky Mountains. In selected municipalities and possibly following a disaster, this assumption may prove to be untrue. (See Selkregg et al., 1984, p. 185, for seismic code disputes even in seismic zone 4.) Nevertheless, we further propose for analysis purposes that the two eastern Model Codes -- the BOCA National Building Code (formerly the Basic Building Code) published by BOCA and the Standard Building Code (SBC) published by SBCCI -- incorporate by transcription the National Earthquake Hazard Reduction

Table 3-2

Building Practices Analyzed

Number	Brief Description
100	In seismic zone 2, design new commercial buildings in accordance with adequate seismic code provisions
110	In seismic zone 3, design new commercial buildings in accordance with adequate seismic code provisions
120	In regions of seismic zone 2 where high catastrophic loss potential exists (zone 2*), require seismic zone 3 detailing requirements for new commercial and governmental buildings
130	In seismic zone 2, design new residential buildings in accordance with adequate seismic code provisions
140	In seismic zone 3, design new residential buildings in accordance with adequate seismic code provisions
150	In seismic zone 2, design new governmental buildings in accordance with adequate seismic provisions
160	In seismic zone 3, design new governmental buildings in accordance with adequate seismic provisions
170	In seismic zone 2, seismically retrofit all "potentially hazardous" buildings
180	In seismic zone 3, seismically retrofit all "potentially hazardous" buildings
190	In seismic zone 4, seismically retrofit all "potentially hazardous" buildings
200	In seismic zone 2, seismically retrofit all poorly anchored or poorly reinforced wood frame dwellings
210	In seismic zone 3, seismically retrofit all poorly anchored or poorly reinforced wood frame dwellings
220	In seismic zone 4, seismically retrofit all poorly anchored or poorly reinforced wood frame dwellings
230	In seismic zone 4, reinforce/anchor/or brace parapets and ornaments to withstand 50 percent of seismic design forces specified in a current model code
240	In seismic zone 4 require that gas water heaters be strapped to structural framing in all multi-family dwellings and apartments (two-family dwellings and above)
250	In seismic zone 3, seismically anchor or restrain all life-safety related equipment (see Table 3-4) in essential buildings, public schools (including colleges), buildings whose primary function is assembly for more than 300 people, other public buildings, and for buildings with more than 500 occupants
260	In seismic zone 4, seismically anchor or restrain all life-safety related equipment in buildings referenced in number 250.

Program (NEHRP) seismic design provisions. Program administrators may in the future consider whether or not 1992 ASCE/ANSI provisions satisfy national seismic design code requirements, and so can be regarded as the equivalent to incorporation of NEHRP seismic provisions.

Uniformity of seismic design provisions is very important for (1) removing competition among jurisdictions (often neighboring) with respect to seismic codes in place and (2) providing greater uniformity of standards for reducing underwriting costs for writing earthquake insurance. Since many municipalities regularly adopt one of these two model codes, incorporation of adequate seismic provisions in these model codes would be an important step toward their implementation in local municipalities throughout the country. Since losses are reduced only if these provisions are adopted and enforced, the project team suggested for evaluation a loss-reduction measure that uniform seismic design provisions be adopted and enforced, especially in the eastern United States. At the same time, this recommendation recognizes the important role of the three major model codes in construction practices throughout the United States.

For purposes of analysis, we also propose that the concept of "seismic zone 2*" be incorporated into model codes. This concept recommends that seismic zone 3 detailing practice be required in those seismic zone 2 regions exhibiting high catastrophic loss potential (hence 2*)[2]. The expression "high catastrophic loss potential" is important from an earthquake insurance standpoint since, as explained in section 3.0, what makes earthquake insurance different from many other forms of insurance (such as life and casualty) is that <u>aggregate earthquake losses are characterized by extreme fluctuations on a year-to-year basis</u>. Regions with high catastrophic losses are more likely to trigger state, regional, and national concerns as associated effects ripple throughout the economy.

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2. One early step in the development of a federal earthquake insurance program would be to work with code-making organizations to determine how to define seismic zone 2*. Possible operational definitions of seismic zone 2* include

- o those regions where PGA_{2500}/PGA_{500} exceeds a specified number such as 1.5,
- o those regions where PHV_{2500}/PHV_{500} exceeds a specific number such as 1.5, or
- o those regions where direct losses due to earthquake could exceed a given amount (such as $5 billion).

In these definitions, PGA represents peak horizontal bedrock acceleration, PHV represents peak horizontal bedrock velocity, and subscripts refer to the mean return interval at a given site for these estimates. Use of such site-specific probabilistic shaking hazard estimates could serve to define zones with "high catastrophic loss potential," but it would need to be understood that these estimates render the interpretation of "high catastrophic loss potential" as being building-specific rather than as area-wide or regional.

For programs covering existing buildings, we define potentially hazardous buildings as those buildings which have high damageability and whose direct damage poses significant life-safety risks. In order to simplify the administrative application of the expression "potentially hazardous building," we define for public policy purposes this expression in terms of a list of nine construction classes in Table 3-3. These generally exclude single-family dwellings and duplexes, although the potential hazards of these buildings (except for

Table 3-3
Potentially Hazardous Building Construction Classes
Identified for Public Policy Purposes

(1) Buildings with unreinforced masonry bearing walls, which do not have complete or adequate load paths for seismic forces.

(2) Concrete tilt-up or reinforced masonry structures with flexible roofs. Flexible roofs include those of wood or steel deck without concrete fill. Structures having one or more of the following inadequate features:
- (a) wood ledgers used in cross-grained bending or tension,
- (b) no bolts or anchor straps for anchorage of walls to roof diaphragm,
- (c) excessive spacing or inadequate capacity of roof to wall anchors,
- (d) chord elements that are discontinuous (not supplied with continuity plates, etc.), and/or
- (e) inadequate connection of tilt-up wall panels to foundation.

(3) Non-ductile concrete frames -- concrete moment-resisting frames not conforming to the detailing provisions of the 1976 or later editions of the Uniform Building Code (UBC), including "pre-cast" frames.

(4) Buildings with "soft" or "weak" first stories -- particularly those having story strengths less than 65 percent of the strength of the story above, as per 1988 UBC.

(5) Buildings having unreinforced or inadequately braced parapet walls or inadequately attached exterior ornamentation.

(6) Buildings with inadequately attached or rigidly attached (inadequate allowance for story drift) exterior glazing or pre-cast concrete, masonry, or stone curtain wall panels.

(7) Unreinforced masonry "infill" exterior walls.

(8) Unreinforced masonry interior partitions or "infill" walls in stairwells and elevator shafts.

(9) Buildings where no lateral force resisting system is present or can be identified either for the whole building or for one story of the building. Buildings in which the seismic lateral force resisting system is incomplete, or has significant gaps that could allow portions of the structure to collapse.

predominantly wood-framed residential construction) remains to be analyzed. Certain classes of one- and two-story wood frame residential construction are not so "potentially hazardous" as they are highly damageable (i.e., having high likelihood of direct property damage without there being a correspondingly high life-safety hazard). (See, for instance, building practices 210 and 220 in Table 3-2.) Unfortunately, however, in the October 17, 1989, Loma Prieta earthquake, five deaths were reported in three- and four-story wood-frame residences (with weak or soft stories) in the Marina District of San Francisco. Likewise, significant numbers of deaths were associated with wood-frame dwelling damage in the 1906 San Francisco earthquake (Hansen and Condon, 1989). The existing stock of buildings that are either "potentially hazardous" or have high property damage potential is very large. (See Petak and Atkisson, 1982; Algermissen et al., 1988; Hopper et al., 1975; CSSC, 1985a; May et al., 1989; Taylor et al., 1988.)

Table 3-4 lists examples of life-safety related equipment (i.e., equipment whose failure can lead to or exacerbate life-safety hazards) associated with LRMs 250 and 260 in Table 3-2. Later in this section and in sections 5 and 6 we discuss possible roles of life-safety protection programs in loss-control programs involving federal insurance involvement. As with landuse elements, we characterize at the end of this section additional supporting measures for building practice LRMs.

Table 3-4
Examples of Life-Safety Related Equipment

- Emergency generators including batteries and fuel tanks
- Fire/water storage tanks and pumps
- Boilers and other equipment using natural gas
- Vessels and their support structures which contain sufficient quantities of substances which, if released, could endanger the general public. These should primarily include liquified gases which can form heavier-than-air vapor clouds, and which are either explosive or toxic
- Elevators and elevator equipment
- Emergency communication equipment

General Remarks on Loss-Reduction Activities Selected for Analysis

When analyzing the candidate activities listed in Tables 3-1 and 3-2, we have included the following structural subcases as appropriate:

- o masonry (unreinforced versus partially reinforced)
- o cast-in-place concrete frames (non-ductile versus semi-ductile or with concrete shear walls)
- o tilt-up shear walls (unimproved or seismically improved)
- o pre-cast concrete frames (non-ductile versus semi-ductile or with concrete shear walls)
- o parapets/ornaments (unbraced versus braced or removed)
- o wood-frame dwellings (not anchored to foundation or with unreinforced cripple walls versus anchored or with wall reinforced at foundation)
- o chimneys (unreinforced versus reinforced or removed)
- o dwellings with story over garage (unreinforced versus reinforced)
- o mobile homes (unbraced versus braced)

This list does not include steel frame structures for which seismic design requirements are generally less expensive and retrofit possibilities are more dubious.

The types of activities and subcases selected for analysis, with a few exceptions, fit into what we shall call <u>community-based</u> programs. Currently, life-safety, economic, political, or legal reasons may lead to individual instances of exemplary seismic safety practices. Especially within higher seismic regions, individuals or firms may on their own decide to build to high seismic standards, to restrain, anchor, or isolate equipment and contents, and to retrofit buildings to higher seismic standards. Owners or property managers may voluntarily decide, or decide based on existing market incentives, to include seismic safety practices that exceed existing regulations and code requirements. Selected insurance companies, as part of their business strategy, may systematically encourage various loss-reduction activities and may provide premium reductions (rate credits) as means to provide incentives for these measures.[3] These types of risk-reduction activities are based on unique motivations or cir-

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3. As later indicated, virtually all prudent insurers will provide some degree of partially risk-based rates to minimize adverse selection, or poor risks at average or flat rates. The degree to which underwriting efforts are made to rate accurately, to avoid poor risks, and to assist clients in reducing losses will depend in the private market on business considerations.

cumstances. Because such motivations or circumstances occur only randomly or rarely, loss-reduction also occurs only randomly. That is, the programs are not community-based.

In contrast, community-based programs generally require some degree of regulation including enforcement at local, state, or federal levels and generally require uniform application. Additionally, most activities listed in Tables 3-1 and 3-2 will require some degree of of consolidation of state and local government resources. In some instances it may be advisable to provide better information to owners, insurers and others in an effort to involve competitive forces in encouraging implementation of loss-control measures.

The application of regulation to loss-control programs that emphasize damage-control also implicitly recognizes concerns for life-safety, and vice-versa. Since direct damage to structures and contents is the primary cause of deaths and injuries in earthquakes, reduction in property damage is the primary means to effect reductions in casualties. As a consequence, **a comprehensive program designed to reduce property losses will in turn have the benefit of reducing expected casualties**. (This of course does not imply that each increment of property-loss reduction has a corresponding increment in life-safety protection. For instance, adequate seismic design of new concrete and masonry frame structures may have high casualty reduction benefits per dollar spent. In contrast, reduction in property damage to low-occupancy and one- and two-story buildings and wood-frame structures, as well as to existing buildings, may have lesser life-safety benefits per dollar spent.) Additionally, the use of civil and police powers to enforce regulation may be significantly questioned if damage-control alone is regulated, but the use of such authority is generally justified by the clear presence of safety concerns. Hence, with a few exceptions, the community orientation of many of the candidate activities, recognizing associated life-safety goals, is consistent with a comprehensive program to reduce expected property losses associated with earthquakes.

3.3 Socioeconomic Analysis of Technically Feasible Loss-Reduction Activities

This section reviews the process of socioeconomic analysis, details the methods used to estimate costs and loss reductions, and summarizes the results of the socioeconomic analyses of technically feasible loss-reduction activities listed in Tables 3-1 and 3-2 as they relate to cost-effectiveness. This analysis of cost-effectiveness is an essential ingredient in a full-fledged consensus process for identifying recommended LRMs, since without this analysis LRMs might be proposed that have appeal to a wide variety of interested parties but that have low benefits relative to their costs.

Process of Socioeconomic Analysis

Figure 3-2 identifies the steps taken to accomplish the socioeconomic analysis. By and large, this analysis evaluated candidate activities on two grounds

- o economic efficiency or cost-effectiveness and
- o economic allocation -- identification of those stakeholders who benefit from and those stakeholders who pay for implementation of loss-reduction activities.

For this project, an interactive model was developed as a means to provide this evaluation. For each analyzed activity, this model yields aggregate benefit/cost ratios and also produces dollar estimates of costs and benefits to diverse stakeholders. Sensitivity analyses were performed relative to some of the many parameters that could affect outcomes.

Relative to the classification of risk analysis methods discussed in Section 2, the method used in this project for socioeconomic analysis has been probabilistic site-specific, which is effective for defining long-range costs and benefits. Costs for loss-reduction measures include chiefly construction costs with small percentages for local administrative costs. Benefits include the entire stream of expected future benefits in constant dollar values discounted to reflect the value of current investment capital. At the most restrictive level, only reduction in direct property losses were considered among benefits. At less restrictive levels, reductions in casualties, in the need for temporary housing, and in business interruption were also considered among benefits.

This expected annual loss methodology ignores large-scale fluctuations in loss levels that may occur over multiple-year periods of time. Large-scale fluctuations often discourage capital outlays, since returns may not be immediate or may not occur within a stakeholder's time-frame of interest. During the Project Workshop participants re-affirmed the use of the interactive model, but encouraged the use of probabilistic multisite methods and further examination of secondary and higher order economic losses. Should a fuller examination be made of these issues, probabilistic multisite methods would be desirable. These have the advantage of defining various threshold level losses (such as losses resulting from mortgage defaults as they affect lenders, and ultimately the federal government and/or catastrophe insurers) that can create secondary financial losses through bankruptcies, insolvencies, defaults, the need for federal assistance, and the like.

The interactive model was used in order to

- o assure that activities identified for inclusion as LRMs in a federal insurance program are economically sound (i.e., have benefits which exceed costs), and

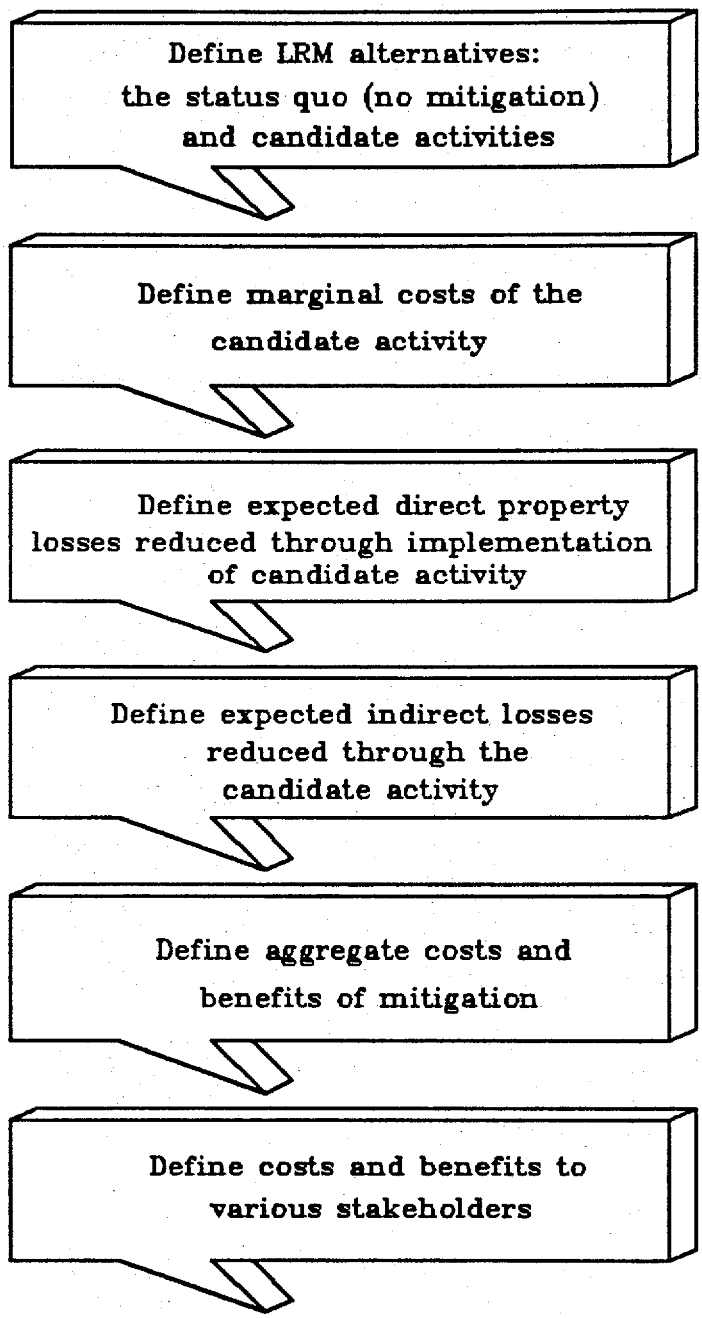

Figure 3-2. Steps in Socioeconomic Analysis

- o provide a preliminary determination of who pays for and who benefits from specific LRMs.

Thus, the cost-effectiveness analysis served to assure that selected activities would not involve poor economic decisions and to provide data with which to evaluate candidates relative to cost/benefit criteria. The stakeholder analysis, to the degree possible in this project, provided further important information regarding the acceptability of candidate activities to various stakeholders. In application, this information can be used to determine, to the extent possible within the limitations of this project, the degree to which various stakeholders who benefit from mitigations should bear the cost of their implementation. For instance, if lending institutions benefit from cost-effective loss-reduction measures, then it is at least conceivable that they should bear the burden of some of the costs of these LRMs. Such considerations are the subject of Sections 4 and 5.

It should be noted that

- o The decision procedures used here permit a continuous LRM evaluation scale largely dependent on the discount rate selected.[4] (Although project workshop participants favored a three percent real discount rate, OMB Circular A-94 requires a ten percent discount rate, and no discount rate is easily warranted with respect to lives saved.)

- o Numerous individual decision situations are reflected in the real world (and in potential distributions used for such parameters as income level, site-specific seismicity factors, deductible levels, limits of liability, and premium levels under different kinds of federal involvement, for both earthquake and non-earthquake insurance). Neither this range of cases nor helpful human behavioral models can be reflected in the limited mechanical cases produced for this project.

- o The model as developed applies to individual decision-makers, and hence accounts neither for widespread decisions nor for community impacts (such as those resulting from large-magnitude earthquakes) of those decisions.

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4. Discount rates purport to quantify the time-value of money. Money today is more valuable than money tomorrow -- even discounting for inflation -- to the extent that money as capital has an investment earning power. Thus, money may earn at x% above inflation.

For public policy analyses, this earning power of money has many critical implications for the benefit-cost ratios developed. Using the variable x% allows for a gradated or continuous evaluation of LRMs in terms of the discount rate at which they would have a favorable benefit/cost ratio. (See Taylor, Atkisson, and Petak, 1981.)

The real discount rate is the constant dollar/earning value of current money, and is used as a continuous interactive parameter. Hence, an LRM may be evaluated in terms of the lowest discount rate at which its benefit-cost ratio exceeds unity. Discount rates to be used are subject to many controversies.

Estimations of Costs and Expected Annual Direct Loss Reductions Resulting from Implementation of Candidate Loss-Reduction Activities

In order to perform socioeconomic evaluations of mitigations, one must have available data that at the very least can be used to indicate the costs and benefits of mitigations. Appendix B presents the results of analyses performed to estimate

(1) risk levels (degree of loss) associated with various levels of seismic (earthquake) frequency and intensity,

(2) dollar values for both implementation costs and loss-reduction benefits of candidate building practice LRMs, and

(3) dollar values for both implementation costs and loss-reduction benefits of candidate landuse planning LRMs.

Again, it should be noted that estimates relate to expected <u>annual</u> direct loss reductions and were designed for average conditions. Annual direct loss reductions incorporate all possible earthquakes affecting buildings analyzed, not merely rare serious ones. As indicated in Eguchi et al. (1989), ignoring effects of smaller but damaging earthquakes is a serious error not only in earthquake insurance rating but also in analysis of the benefits of LRMs.

In order to account for variations in frequency of earthquakes of varying seismic intensities, short-cut methods were used that considered both (a) variations in seismic intensity levels (owing to distance from sites to various earthquake sources) and (b) effects of strong ground motions on various local soils. (See Appendix B.) Assumptions made are conservative since one goal of this analysis was to eliminate candidate LRMs which are, as a general rule, poor investments. Even more conservative assumptions typically were made with respect to landuse measures mitigating surface fault rupture, liquefaction, and landslide hazards. Sensitivity of outcomes to variations in estimates of frequencies of shaking intensities were analyzed within the interactive model. For both shaking intensity and analysis of potential permanent ground displacements, it is possible at greater cost to provide much finer estimates. Current methods for probabilistically analyzing liquefaction and landslide hazards require additional systematic applied research in order to become credible for microzonation analyses (Eguchi et al., 1989).

Seismic vulnerability estimates were derived largely from ATC-13 (1985), Wiggins and Taylor (1986), and engineering judgment. (See Appendix B.) As indicated in Wiggins and Taylor (1986), for selected classes of construction, procedures previously used may significantly underestimate the losses reduced through seismic improvements. Consequently, sensitivity analyses were performed in order to determine the effects of using diverse seismic vulnerability estimates to evaluate specific loss-reduction activities.

Estimates of the direct initial costs of loss-reduction activities were derived from a number of sources along with engineering experience. These represent average initial cost estimates for instances when the activity is technically feasible. This study as well as previous studies strongly indicates that initial cost estimates are an extremely critical parameter in the assessment of LRMs (see Taylor, Atkisson, and Petak, 1981). By the same token, techniques developed in order to reduce expected capital outlays needed to achieve seismic design and redesign objectives -- even by small margins -- when applied broadly can have potentially large-scale aggregate effects in reducing the costs of losses associated with earthquakes. In other words, research programs that yield small percentage reductions in seismic design and redesign costs (e.g., 0.1% of replacement value) can have large-scale aggregate effects (e.g., millions of dollars in reduced costs).

In addition to initial outlay costs and estimates of direct property benefits for specific LRMs, an adequate risk-and-decision analysis requires consideration of secondary costs and losses associated directly with the property and its stakeholders. Appendix C discusses additional estimates of economic and stakeholder costs and losses.

In addition to estimates of direct property losses, analysts considered losses associated with

- o temporary housing,
- o business interruption,
- o deaths and injuries,
- o the cost of money, and
- o insurance premiums.

Not considered were losses associated with

- o contents,
- o infrastructure facilities and fire following,
- o release of toxic or hazardous chemicals,
- o transaction, foreclosure and business closure (except for crude assumptions on loadings for premiums),
- o post-disaster clean-up,
- o price deflation,
- o unemployment resulting from general economic decline.

Results of the Economic Efficiency Analysis

In order to rate candidate LRMs in terms of cost-effectiveness, a three-tier criteria approach was used. This permits a continuum of economic evaluations with those LRMs that pass at tier 1 obviously passing at tiers 2 and 3, those passing at tier 2 obviously passing at tier 3, and those failing at tier 3 obviously failing at all tiers. This continuum of economic evaluations recognizes that diverse economic criteria, such as are implicit in discount rates selected, may be used to determine economic acceptibility.

At tier 1, the most rigorous, only direct property losses were considered, and an eight (8) percent discount rate was used. Only the most cost-effective LRMs satisfy tier 1 criteria. At tier 2, clear monetary considerations were included as secondary losses associated with temporary housing, business interruption, and deaths and injuries were considered, and a three (3) percent discount rate was used. Deaths were calculated to have an average value of $300,000 (as a monetary measure only), which represents a conservative appraisal of a lifetime discounted income. Tier 2 represents the level for sound economic policy supported by project workshop participants. At tier 3, losses above primary and secondary levels were considered, deaths were valued at $1,000,000 (a value exceeding average present discounted value of potential future earnings), and a zero (0) percent discount rate applied. Tier 3 may be appropriate for community health, safety, and welfare programs. LRMs not satisfying tiers 1, 2, or 3 criteria are as a rule not economically sound policies.

The main results of the efficiency (cost-effectiveness) analysis are outlined below. Loss-reduction activity numbers refer to Tables 3-1 and 3-2.

<u>At tier 1</u>, most of the activities covering new seismic design (#s 100, 110, 120, 130, 140, 150, 160) passed, with all cases passing at tier 2. Generally speaking, implementation of seismic building codes has a favorable benefit/cost ratio--even from the standpoint of property loss reductions alone.

Seismic retrofit of unbolted and/or poorly anchored wood-frame residences in seismic zone 4 (# 220) passed at tier 1. The low per-unit cost of this measure combined with significant property loss-reduction make this an economically attractive candidate mitigation measure.

Use of geotechnical means to minimize landsliding, severe liquefaction, and/or subsidence hazards in seismic zone 4 (# 1500) passed at tier 1 for commercial and public developments and for large-scale residential tracts. Economies of scale are significant with respect to residential structures; this measure appears to be economically unattractive for unit-by-unit single-family and duplex residential developments.

At tier 2, seismic retrofit of tilt-up construction in seismic zone 4 (one subcase of # 190) appears to be economically attractive owing to the comparatively low costs of this retrofit. Other economic measures are seismic retrofit of unreinforced masonry structures in seismic zone 4 (another subcase of # 190), and seismic retrofit of tilt-up construction in seismic zones 2 and 3 (subcases of #s 170 and 180).

Also at tier 2, a number of landuse/geotechnical engineering measures passed for residential construction other than single family dwellings or duplexes. These include, for seismic zone 4, restrictions on new development in very active fault zones of deformation (# 1200), in highly susceptible liquefaction zones (# 1700), and in highly susceptible landslide locales (# 2100). For landslide locales, possible purchase of land with conversion to open-space uses can in some cases be economically warranted (# 2300). Considerations of public health and welfare can enter into these landuse decisions. Seismically poor land can also correspond to regions of intensive infrastructure earthquake damage with associated health and welfare concerns (see Selkregg et al., 1984).

Minimization of severe liquefaction and/or subsidence hazards in seismic zone 3 (# 1600) also passed at tier 2 for new commercial and public development. Also, for modifications of commercial structures in severe liquefaction zones in seismic zone 4, use of geotechnical techniques to minimize these hazards passed at tier 2 (# 1900).

Mitigations passing tier 1 and tier 2 represent, as a rule, economically sound policies. These include life-safety factors only in defensible economic terms. Activities that pass at tier 3 represent policies that have lower ratings on economic grounds, but that may be pursued as sound public policies if life-safety hazards, potential community disruption, and other factors are emphasized.

At tier 3, seismic retrofit of unreinforced masonry buildings appears to be warranted in seismic zones 2 and 3 (subcases of #s 170 and 180 in Table 3-2). Seismic retrofit of "potentially hazardous" buildings in seismic zone 4 passes at tier 3 for all pertinent building types (retrofit of tilt-up and unreinforced masonry buildings passed at tier 2) (# 190). Seismic reinforcement/anchorage/bracing of parapets and ornaments (# 230) passed at tier 2.

With respect to landuse measures in seismic zone 4, restriction of new development in moderately active fault zones of deformation passed at tier 3 (# 1300). In seismic zone 3, restrictions of new developments in highly susceptible liquefaction or landslide locales (#s 1800 and 2200) appear to pass at tier 3, as does use of geotechnical techniques to minimize ground failure potential damage whenever major modifications of structures are made in highly susceptible liquefaction zones (# 2000). Seismic retrofit of wood-frame dwellings in seismic zones 2 and 3 (#s 200 and 210) is of marginal cost-effectiveness and needs further examination.

Not passing on any of the three tiers (and as a rule with exceptions that can be assessed through individual benefit-cost analyses) are

- o seismic retrofit in seismic zones 2 and 3 of non-ductile and pre-cast concrete frames (subcases of #s 170 and 180)
- o purchase of existing (undamaged) construction or properties in fault zones of deformation, or zones with severe liquefaction, landslide or rockfall potential (#s 1000, 1100, as illustrations)
- o restriction of new development in moderately active fault zones of deformation in seismic zones 2 or 3 (# 1400)
- o purchase and conversion of land in highly susceptible landslide susceptible locales in seismic zone 3 (# 2400)

Activities numbered 200 and 210 only marginally passed for subcases considered at tier 3. No formal analysis was provided for activities numbered 240, 250, and 260.

3.4 Summary

In this section we outlined the procedures used to identify and define feasible Loss Reduction Measures (LRMs) for possible incorporation in a federal earthquake insurance program. The procedures used involved

1. a thorough information search, which identified 96 earthquake hazard reduction activities for consideration,
2. reduction of this list to 32 loss-reduction activities for further analysis,
3. socioeconomic risk-and-decision analyses to evaluate these 32 loss-reduction activities for cost-effectiveness and stakeholder impact, and
4. a project workshop during which cost-effective loss-reduction activities were further analyzed, synthesized and developed into initially recommended Loss-Reduction Measures.
5. a final advisory panel meeting and review by advisory panel members and other knowledgeable parties of these initially recommended LRMs.

The socioeconomic analysis permitted the evaluation of candidate loss-reduction activities in terms of their cost-efficiency and stakeholder impact. Those that are especially cost-effective include

- o adoption of, compliance with, and enforcement of adequate seismic design provisions in new construction in all seismic zones (with minimal or no costs in seismic zones 0 and 1),
- o seismic retrofit of unbolted and/or poorly anchored wood-frame residences in seismic zone 4, and
- o minimization through geotechnical techniques of severe landslide, liquefaction and/or subsidence hazards in seismic zone 4.

As discussed in the next section, these results were considered further in the course of an acceptability analysis.

4.0 THE IDENTIFICATION, DEVELOPMENT AND EVALUATION OF ACCEPTABLE LOSS-REDUCTION MEASURES

As explained in Section 1, the characterization of earthquake loss-reduction provisions as "feasible" requires that they must prove to be both cost-effective and otherwise acceptable to a wide variety of individuals who will be affected by the measure.

As a result, three processes were utilized to help ensure that recommended loss-reduction provisions would be acceptable.

(1) The socioeconomic analysis conducted as part of this study included an economic allocative or stakeholder analysis of technically feasible loss-reduction activities.

(2) Cost-effective loss-reduction activities were presented to a Project Workshop for further consideration and modification by diverse interest groups.

(3) Initially recommended loss-reduction measures were submitted to advisory panel members and other knowledgable parties at a final advisory panel meeting and through draft final reports.

This section reviews the procedures used to conduct these processes and reports the results of these efforts.

4.1 Economic Allocative (Stakeholder) Analysis

A stakeholder analysis has been developed in this project in order to estimate gains and losses to stakeholders with respect to the status quo and to alternatives so that various loss-reduction policy measures may be recommended. The following stakeholders were considered in the allocative analysis:

- the general taxpayer (the federal government)
- the state taxpayer (for specific state governments)
- the local taxpayer (for specific municipalities)
- lending institutions
- realtors
- developers
- building contractors and subcontractors
- owners
- small businesses
- workers/employees
- tenants
- nonprofit organizations
- low-income residents

- o companies writing earthquake insurance
- o companies writing non-earthquake insurance

These and a wide variety of other stakeholders may be directly involved in a proposed loss-reduction program. In this list, taxpayers are included in three categories in order to evaluate how losses are distributed among individual states and municipalities. Hence, a taxpayer in a highly seismically prone municipality or state may expect to pay higher state or local taxes to offset earthquake damage than a taxpayer in a less seismically prone municipality or state. Accordingly, individuals may have interests that are associated with potentially competing stakeholder claims: one may desire lower earthquake insurance rates for one's residence or business; one may desire lower local, state, and federal tax burdens; one may desire to occupy more seismically resistant buildings; and one may have additional interests in the above stakeholder positions.

Stakeholders do not always accurately evaluate their economic interests. People may support or oppose programs based on only partial or incorrect information. We have conducted a limited stakeholder analysis in an effort to clarify where economic interests in proposed measures lie -- who gains and who pays. In this regard, the stakeholder analysis may estimate gains and losses to stakeholders with respect to

(a) the status quo,
(b) diverse proposed loss-reduction measures, and
(c) alternative types of federal involvements in earthquake insurance.

Thus, stakeholder analyses clarify potential gains and losses to existing or prospective constituencies. These analyses are also useful in determining which public policy vehicles may be useful in view of the stakeholder benefits and costs of a proposed loss-reduction measure.

4.2 Results of Economic Allocative (Stakeholder) Analysis

In discussing the results of the stakeholder analysis, we distinguish among diverse stakeholder populations. In some instances, as with taxpayers, individuals may fall into a number of stakeholder positions (e.g., federal taxpayer, taxpayer for a specific state, taxpayer for a specific municipality).

Key results obtained from the stakeholder analysis include the following:

- o Federal taxpayers currently bear the largest burden of earthquake property losses associated with public and selected private nonprofit buildings. Since current disaster relief policy places the financial burden of recovery on the federal government, the benefit/cost ratio of implementing loss-reduction activities to state and local governments is significantly reduced. In effect, current disaster relief policy serves as a major disincentive to mitigation for state and local and selected private nonprofit buildings.

- o All stakeholders modeled benefit from cost-effective LRMs except for state and local taxpayers for activities pertaining to state and local buildings. This general conclusion may not necessarily hold for short-term owners, tenants, realtors, and contractors, who were not included in the model (in these cases, short-term time horizons, possibly reflected in high discount rates, may need to be considered in the stakeholder analysis).

- o Given current contingent federal liabilities with respect to publicly owned buildings, the costs of federal subsidies for cost-effective LRMs for these buildings can be offset by reduced federal liabilities.

- o Mortgage-lending institutions benefit from cost-effective LRMs. A finer analysis of the risks borne by these institutions is therefore needed in order to estimate more precisely the degree to which these lenders benefit from implementation of LRMs.

- o Workers generally benefit from implementation of cost-effective LRMs owing to reduced expected casualties and unemployment.

- o Since losses in other lines of insurance (auto, theft, etc.) are expected to be reduced by the implementation of LRMs, insurers who write policies in these other lines and who may expect losses after earthquakes benefit from these LRMs.

- o Taxpayers in general gain from cost-effective loss-reduction activities, since their implementation
  - reduces post-disaster loans (subsidies) and grants, and
  - reduces the need for temporary housing (relative to residential LRMs).

- o Tax credits for homeowners who undertake cost-effective loss-reduction activities are not effective vehicles to offset contingent federal liabilities, since benefits of tax credits would largely accrue to higher income segments of the population who are least expected to require post-disaster assistance. A fuller study of the benefits of tax credits would be needed before they should be recommended as means to induce LRMs.

- o Subsidies including tax deductions and low interest loans should be considered for cost-effective commercial seismic retrofit programs to the extent that these programs reduce post-disaster costs of
  - unemployment insurance,
  - workers' compensation claims, and
  - loss of tax revenues resulting from business interruptions and closures.

In review, virtually all stakeholders benefit from implementation of cost-effective loss-reduction measures. The notable exception is the state and local taxpayer and private non-profit institutions eligible for federal disaster assistance, because federal disaster relief assistance policies for public and private nonprofit building provide a disincentive for additional investment in loss-reduction activities. (See Appendix D.)

4.3 The Project Workshop and Final Advisory Panel Meeting

The efforts outlined thus far were ultimately aimed at identifying earthquake loss-reduction provisions which could potentially be worked into a national insurance or reinsurance program. After the socioeconomic analyses were completed, the remaining loss-reduction activities were presented at a Project Workshop for further revision, refinement, and definition as Loss Reduction Measures (LRMs) for potential incorporation into a national insurance or reinsurance program. Afterwards, a final advisory panel meeting was held, and draft final reports were reviewed by advisory panel members and other knowledgeable parties.

The Project Workshop

The Project Workshop was composed of recognized experts and interested and affected parties representing a very broad spectrum of interests, professions, and geographical regions. The workshop was to provide for further consideration of the views of diverse interest groups and to assure that the proposed measures are professionally supportable, and acceptable to communities, the insurance industry and policyholders. The workshop was to encourage the introduction of new information and innovative ideas.

Workshop participants were divided into five working groups:

- o building issues,
- o landuse planning/geotechnical issues,
- o risk analysis issues,
- o socioeconomic/insurance issues, and
- o public policy/legal issues.

The workshop was designed to encourage participants in each of these five topic areas to freely discuss, augment, and revise preliminary findings and finally to develop and evaluate specific conclusions.

In both the landuse and building issues sessions, participants were first asked to review a list of cost-effective loss-reduction measures (LRMs) and to add to this list. Next, positive and negative impacts of these LRMs were to be listed. Then, the resulting LRMs were to be evaluated on the basis of their probability of successful inclusion in a national insurance program. A similar set of steps was used to develop lists of supporting elements -- activities required to initiate, support, or sustain promising LRMs.

The risk analysis session was organized around

- risk analysis methods,
- other model elements of risk analysis, and
- possible uses of risk methods in a federal earthquake insurance program.

First, prepared lists of these methods, elements, and uses, respectively, were added to. Next pros and cons of these lists were discussed. Finally, the resulting lists were evaluated.

The design of the working session on socioeconomic issues was first to augment the list of stakeholders previously modeled, next to evaluate the merits of including various stakeholders, and then to rate the inclusion of these stakeholders in the model socioeconomic analysis. Then, preliminary socioeconomic analysis results were listed, to be added to, discussed, and evaluated.

The working session on public policy/legal issues was designed to evaluate the importance of various political issues relating to LRMs that had been developed prior to the workshop. Advantages and disadvantages of including these and other issues in the public policy analysis were to be listed and evaluated.

The design of the workshop did not include a concerted effort to make every matter discussed and every recommendation developed consistent in each of the five working sessions. For instance, LRMs that may have been added or altered in the building issues and landuse issues sessions were not necessarily specifically evaluated in the session on public policy analysis. For another instance, recommendations developed in one session may have been qualified or discussed in another session. However, the intent of the workshop was to convene recognized experts and interested parties in each of a number of disciplines and interest areas and to have those parties critique, modify, and augment conclusions developed so far in this project. Workshop participants were not asked to provide an overall integration of results.

Also discussed by Workshop participants were status quo obstacles to implementation of LRMs and strategies for overcoming these obstacles. Additional public policy/legal analysis are included in Section 5, with respect to the inclusion of LRMs in various types of federal insurance involvements.

The Final Advisory Meeting and Reviews of Draft Final Reports

The overall integration of results was developed in an initial draft final report which was discussed at a final advisory panel meeting. Owing to the complexity of the report and to serious objections to initial incorporation proposals, especially with respect to federal reinsurance involvement, an additional draft final report was also submitted. These draft final reports were reviewed by advisory panel members, by the project officer, and, through the project liaison, by federal officials on the interagency task force on earthquake insurance.

Although much of the attention of these reviews of draft final reports concentrated on incorporation issues, reviewers also added valuable insights that led to further refinements and revisions of the initially recommended LRMs. One central issue raised in the final Advisory Panel meeting and afterwards was the status of the recommended LRMs: Were they to be explicitly stated in any bills before Congress, were they to be included in administrative guidelines, or were they to be sufficiently detailed to be readily implemented as expressed? Given the consensus process used in this project, it is clear that more specific LRMs than are recommended here would require further administrative and technical discussion. In contrast, inclusion of the LRMs as stated may lead to an undesirable degree of administrative inflexibility. Hence, the LRMs recommended in this project are designed to be used in administrative rules and regulations within existing and/or major modifications of federal programs. Moreover, this report is advisory only to FEMA and so does not reflect their final considerations.

4.4 Cost-Effective LRMs Recommended

LRMs and Supporting Activities/Elements Developed

The landuse and building groups of the project workshop were asked to refine, revise, and augment those loss-reduction activities defined as being cost-effective. The resulting LRMs were then evaluated, and supporting or framework elements were identified and defined. Results of the evaluation process were intended to refer to a likelihood of successful inclusion in a federal earthquake insurance program having a loss-prevention element. This subsection presents the results of those two working sessions as revised by the project team in response to comments by the project advisory panel and other considerations.

<u>Landuse LRMs</u>

Table 4-1 lists promising landuse LRMs, all of which were evaluated by the working landuse group at the Project Workshop as having a high probability of successful inclusion in a federal earthquake insurance program. All four LRMs apply chiefly to seismic zones 3 and 4, although LRM 3, pertaining to post-damage situations, may be extended to seismic zone 2. LRM 1 does not apply as cost-effectively to scattered construction of single-family dwellings, and administrative and legal versions of this LRM may consider scattered or unit-by-unit construction of single-family dwellings as a possible exclusion. The other three LRMs apply to all structures. All four LRMs require governmental regulation as a primary instrument for implementation, and all four emphasize potential permanent ground failures. Local extreme strong motion amplification effects owing to high relative site response factors were added to LRM 2, because an increasing body of evidence demonstrates that these factors are significant contributors to earthquake loss potential. Some concern was expressed over the use of 50 percent of replacement cost as a criterion in LRM 4. In administrative versions of this LRM, consideration may be given to use of "actual cash value" or "market value" in lieu of "replacement cost."

Table 4-1

Recommended Landuse LRMs
(Applicable only in seismic zones 3 and 4)

<u>New Developments</u>

LRM 1 Require in high liquefaction susceptible zones that geotechnical techniques be used to minimize potential ground failures for:

- o new commercial, public, and residential subdivision development, and
- o major modifications of commercial, public and residential subdivision development. (Exceptions of scattered construction of single-family dwellings may be considered in legal and administrative versions of this loss-reduction measure.)

LRM 2 Use zoning ordinances, subdivision ordinances and other techniques to control new development in active fault zones, high site amplification, landslide and liquefaction susceptible zones.

<u>Existing Developments</u>

LRM 3 Permit reconstruction or replacement of existing development in areas identified as active fault zones, high landslide, or liquefaction susceptible zones experiencing damage of more than 50% of its replacement value only if the identified risk is reduced to an acceptable level. Consider purchase of existing damaged properties in high landslide susceptible zones unless suitable measures are used to protect existing development from damage.

LRM 4 Permit no additions to buildings in areas identified as active fault zones, high landslide or liquefaction susceptible zones unless the risks are reduced to an acceptable level, except additions to single-family dwellings up to 50% of the replacement cost, which can be made without such risk reduction.

In evaluating these four LRMs, the working group emphasized two general advantages:

- o reduction in expected property losses (reduction in exposure/risk, limitation of number of potentially hazardous buildings, limitation of potential losses to the housing stock, and reduction of post-disaster clean-up costs), and
- o improvement in public safety and health in regions where damage potential is high to such infrastructure facilities as sewage lift-stations, natural gas mains, and water mains.

The working groups highlighted the following general disadvantages:

- o apparent loss of market property value in high hazard zones (Further legal and socioeconomic analysis is needed to determine whether or not externalization of earthquake risks can be assumed in assessment of market values.), and
- o possible litigation and political dissension resulting from this loss of property value.

<u>Supporting Elements for Landuse LRMs</u>

Table 4-2 provides a list of candidate activities that support or sustain LRMs described in Table 4-1 as determined by the workshop attendees. In the main, these are restricted to seismic zones 3 and 4 for which available data have already been developed. Hence, these supporting activities do not require huge sums of money as some reviewers of earlier final drafts have contended.

L1 consists of small-scale maps needed principally to define seismic zones. These maps are being updated continually. The remainder of the supporting elements apply primarily in seismic zones 3 and 4.

Intermediate scale maps (L2) requiring examination of local geologic effects on strong ground motion are helpful in defining "poor sites" relative to strong ground motion. Their identification is useful in further delineating liquefaction/subsidence/landslide hazards. Furthermore, as landuse planning evolves, inclusion of LRMs pertaining to poor sites will gain more support. The project director strongly endorses continuing improvements of building codes in order to determine the feasibility of including microzones for poor soils within the seismic provisions of those codes. Moreover, consideration of poor sites relative to strong ground motion are incorporated into building practice LRMs.

L3 requires maps of active fault zones of deformation in seismic zones 3 and 4. The State of California already has such maps, and these are also available from Utah Geological and Mineral Survey for portions of the Wasatch Front, Utah. As the socioeconomic analysis indicated, in many cases, these maps have more symbolic than economic value, although they are useful in general earthquake source studies and in some cases indicate fault creep (gradual movement of identified faults) and additional hazards (new faults). Cases in which development in moderately active fault zones of deformation can be avoided -- without significant economic loss -- should be encouraged. These maps can also be extremely useful in controlling the development of critical and very high occupancy structures.

Table 4-2

Activities Supporting Recommended Landuse LRMs

Supporting Element	Description
L1	For the entire United States, development of small scale maps (1:5,000,000) of ground motion, evaluated by an expert panel.
L2	For urban areas with a minimum population (e.g., 50,000) development of intermediate scale maps (1:100,000) of ground motion that include examination of local geological effects on strong ground motion (e.g., maps of relative site velocities for different spectra).
L3	Compilation and as necessary development of large scale maps (1:24,000) of Quaternary surface faulting within a 50-mile band outside the perimeter of urban areas having a minimum population. Compilation and development of intermediate scale maps (1:100,000) elsewhere in seismic zones 3 and 4.
L4	Compilation and development of large scale liquefaction and landslide high seismic susceptibility maps (1:24,000) for urban areas having a certain minimum population. Greater attention should be placed on quantitative interpretation of such expressions as "high susceptibility." Areas mapped should be large enough to accommodate short-term growth in undeveloped areas around the city.
L5	Construction of information databases and transfer mechanisms so that the foregoing maps may be readily available and understandable to local officials, realtors, developers, insurance companies, and the general public.
L6	Requirement that general plans include a seismic safety element that sets development policy for local geological hazards including high relative site response factors, fault zones, and regions of high liquefaction and/or landslide susceptibility.
L7	Development of requirements that in areas identified as active fault zones, and high landslide or liquefaction susceptible zones that a geologic/geotechnical report be prepared for critical facilities, high-occupancy buildings, new subdivisions, and major modifications of high-occupancy (and/or critical) buildings, and that these be reviewed by a suitable licensed professional.
L8	Development of guidelines for preparation and review of geologic/geotechnical reports.
L9	Provision of resources for state and local programs, procedures, and staffing to effect LRMs.

L4 requires landslide and liquefaction maps. Data for these, for instance, are available for portions of California, Alaska, Utah, Nevada, and Washington. Of special interest is more detailed delineation of very high susceptibility zones, and, for many purposes, the desirability of improved techniques to quantify these hazards (see Eguchi et al., 1989). The broad zones as defined for the Wasatch Front, for instance, could be more narrowly defined based on future detailed site investigations and research that better determines probabilities of liquefaction-induced ground failure and that provides more consistent quantitative definitions of "high" and "very high." (See Anderson et al., 1982; Idriss et al., 1986; Taylor et al., 1988.) Economic means to develop seismically-induced landslide maps should be encouraged with emphasis possibly on areas where previous landslides have occurred. Once again, quantitative interpretation of landslide susceptibilities needs to be improved.

L5 encourages the development of systematic means for the transfer of these maps to interested parties.

L6 requires a seismic safety element within general plans of municipalities with a certain minimum population. This activity is regarded as a supporting element rather than as an LRM because there has been considerable controversy over the effectiveness of seismic safety planning elements.

L7 requires geologic/geotechnical reports for critical facilities, high-occupancy facilities, new subdivisions, and major modifications of high-occupancy (and/or critical) buildings.

L8 requires guidelines for preparation and review of these geologic/geotechnical reports.

L9 was added by the project director based on Selkregg et al., 1984, pp. 160ff. Support for capable state and local government LRM programs, procedures, and professional staffing is an essential means to carry out loss-reduction policy. Continuity of organizations and professional staffing is needed to take advantage of loss-reduction opportunities. Appropriate capabilities include technical knowledge. The federal government may justifiably provide partial financial support for these programs, procedures, and staffing to the extent that landuse measures are expected to offset existing contingent federal liabilities. This support (made later also with respect to building LRMs) is consistent with the recommendations by S. Scott (1988a and b) that implementation needs both (a) local agents of experimentation and innovation and also (b) continuing education and training programs.

For the bulk of these supporting elements, many previous investigations and activities can be used to provide a basis for LRMs proposed, especially in Alaska, California, Utah, and Washington.

LRMs Related to Building Practices

Ten LRMs affecting building practices were carefully formulated by workshop participants and were evaluated as having a high probability of successful inclusion in a federal earthquake insurance program. An eleventh (LRM 6) was added by the project director on consideration of a primary program that includes residential structures. These LRMs are listed in Table 4-3.

Of the LRMs affecting building practices, those evaluated most highly in terms of the likelihood of successful inclusion in a federal earthquake insurance program having a loss-reduction element were:

LRM 7 - in seismic zones 2, 3, and 4, design of new essential buildings and public schools (including colleges and universities) in conformance with current model code seismic provisions.

LRM 10 - seismic retrofit of unreinforced masonry buildings in seismic zone 4.

LRM 11 - seismic securing/strengthening of building parapets and external ornamentation in seismic zone 4.

LRM 12 - seismic retrofit of potentially hazardous essential buildings and public schools (including colleges and universities) in seismic zone 4.

LRM 13 - in seismic zones 3 and 4, inspection and disclosure of anchorage and presence of unbraced cripple walls at time of property transfer for buildings including one- and two-family dwellings and of anchorage of mobile homes.

LRM 14 - In seismic zone 4, state law should require that gas water heaters in new and existing multi-family dwellings be braced or strapped to structural framing.

Evaluated almost as highly are

LRM 5 - incorporation of NEHRP seismic provisions in eastern model codes (seismic zones 0, 1, 2, 3) and

LRM 15 - require seismic retrofit of pre-1976 concrete tilt-up construction in seismic zone 4 within 10 years.

Evaluated as passing (as less convincing to workshop participants) are

LRM 8 - adding superior detailing requirements in seismic zones currently designated 2 with high catastrophic loss potential.

LRM 9 - in seismic zones 3 and 4, disclose a "hazard rating" to potential buyers well before the time of escrow.

Table 4-3
Recommended Building Practice LRMs

<u>New Construction</u>

LRM 5 Eastern model codes shall be encouraged to incorporate (adopt by transcription) the latest version of the NEHRP seismic provisions. All model codes should incorporate a geotechnical component that considers local site amplification effects on strong ground motion and minimization of potential ground failure effects.

LRM 6 Building regulatory authorities should adopt and enforce model codes that have adequate seismic provisions for one- and two-family dwellings and anchorage of mobile homes. The building code should apply also to repairs of earthquake-damaged buildings to assure that losses are not repeated in subsequent earthquakes.

LRM 7 In seismic zones 2, 3, and 4, new essential buildings and public schools, including colleges and universities, should be designed in conformance with current model code seismic provisions.

LRM 8 In seismic zones currently designated 2 but with high seismic catastrophic loss potential (designated 2*) model codes should require the detailing requirements applied to zones of high seismicity.

LRM 9 For new construction in seismic zones 3 and 4, a building "hazard rating" must be disclosed to potential buyers well before the close of escrow.

<u>Existing Construction</u>

LRM 10 In seismic zone 4, local jurisdictions should institute ordinances with requirements for seismic retrofit of unreinforced masonry (URM) bearing wall buildings. These buildings should be required to be upgraded to a minimum level or else demolished within a 20-year period.

LRM 11 In seismic zone 4, local jurisdictions should institute ordinances for the securing/ strengthening of building parapets and external ornamentation within a 20-year period.

LRM 12 In seismic zone 4, potentially hazardous (other than URM) essential buildings and public schools including colleges and universities must be retrofitted or phased out within a 20-year period.

LRM 13 In seismic zones 3 and 4, inspections of buildings including one- and two-family dwellings and anchorage of mobile homes should be performed prior to significant financial commitment or property transfer and hence well before the close of escrow. A report to the potential buyer should indicate whether or not:

a. the dwelling is anchored to the foundation,
b. unbraced cripple walls are present, and
c. gas water heaters (if present) are adequately braced or strapped to the framing.

LRM 14 In seismic zone 4, state law should require that gas water heaters in multi-family dwellings (new and existing) be braced or strapped to structural framing.

LRM 15 In seismic zone 4, concrete tilt-up construction which does not have adequate roof-to-wall anchors and continuity ties shall be required to be retrofitted within 10 years.

LRM 9 has been the subject of several criticisms by project participants. First, studies have shown that disclosure requirements in California have sometimes had little if any discernible effect on purchases in active fault zones in California. (See Palm, 1981.) However, LRM 9 emphasizes disclosure well before the close of escrow. Second, if LRM 5 is accepted, the LRM 9 might initially appear to be redundant. Yet, even if LRM 5 is adopted, LRM 9 provides a basis for distinguishing between buildings conforming to current model seismic code requirements and older buildings that may not so conform. More elaborately, a hazard rating system can include the following categories:

- Conforming to current model seismic code requirements
- Potentially seismically hazardous (as defined in Table 4-3)
- Nonconforming to current model seismic code requirements and not potentially hazardous
- Seismically retrofitted to 65% of current model seismic code design force requirements

Although LRM 9 is not so essential as most of the other LRMs recommended, efficient use of such a hazard rating system can help in

- insurance rating,
- mortgage lending, pension fund, mortgage security, and other financial decisions which are concerned with potential catastrophic losses from mortgage defaults, and
- building purchase decisions.

In short, LRM 9 has the potential to discourage through a wide variety of financial incentives the prolonged use of potentially hazardous buildings.

LRM 5 recognizes the autonomy and importance of the three major model codes in the United States, and so does not propose a national building code. Moreover, LRM 5 acknowledges the leadership of the Structural Engineers Association of California in developing seismic provisions for the Uniform Building Code. In two years, LRM 5 might be revised after adequate review to consider incorporation of ASCE/ANSI (American Society of Civil Engineers/American National Standards Institute) seismic provisions.

One LRM noticeably absent from workshop discussions, but recommended in LRM 6, is the development and incorporation in model codes of adequate seismic provisions for residential construction. Progress has already been made in developing agreement among model code organizations on codes for residential construction. (See CABO, 1989.) These codes represent suitable minimum standards for an LRM in a federal program. Based on codes represent suitable minimum standards for an LRM in a federal program. Based on other Workshop recommendations on seismic building codes, the project director believes that LRM 6 would also be rated highly.

The LRMs thus presented for inclusion in a federal earthquake insurance program having a loss-reduction element cover a wide range of structures, from public to residential to commercial/industrial, and all seismic zones. The LRMs proposed also differ significantly with respect to socioeconomic criteria. In particular, life-safety factors and ease of administration were emphasized in

- o LRMs proposed for essential facilities, and
- o LRMs proposed for seismic retrofit of "potentially hazardous" buildings (only some of which are clearly cost-effective).

An optional LRM, not discussed in the workshop but clearly technically feasible is the anchorage or restraint of life-safety related equipment (see Table 4-4) in essential buildings in seismic zones 3 and 4. This and many other candidate LRMs may on further examination, or with additional research, be found to be cost-effective and acceptable. Review of research and applications advances, including those in using base-isolation strategies for design and retrofit, should be used to reassess periodically cost-effective and acceptable LRMs.

Supporting Elements for Building Practice LRMs

Table 4-4 summarizes supporting elements needed for successful implementation of the building LRMs listed in Table 4-3. All supporting elements except B6, B7, and B8 were evaluated highly by participants in the building working sessions. B6, B7, B8, B9, and B10 were added by the project director in response to later considerations provided by project reviewers.

Except for B2, which applies to new construction in seismic zone 2, and B8 and B9, which apply generally, the supporting elements are designed chiefly for existing construction in seismic zones 3 and especially 4. The marginal costs of these supporting elements are low.

B1 defines "potentially hazardous" buildings as a means to support LRM 6, LRM 15, and partially risk-based rating systems (See Table 4-3).

B2, which provides for the definition of seismic zone 2*, facilitates application of LRM 8. Our previous discussion in subsection 3.2 describes alternative definitions of seismic zone 2 that could be considered in determining the application of LRM 8.

Table 4-4

Supporting Elements for Recommended Building Practice LRMs

Supporting Element	Description
B1	Definition of "potentially hazardous" buildings as in Table 4-3.
B2	Definition of seismic zone 2* as those seismic zone 2 areas with high seismic potential at extended recurrence intervals and/or with high seismic loss potential.
B3	Definition of criteria and a program for seismic evaluation and retrofit of existing buildings.
B4	Provision for limitations on liability of local jurisdictions and their building official(s) when they provide and permit criteria (as in B3) for evaluation and retrofit design which is less stringent than building code requirements for new construction.
B5	Permission for voluntary seismic upgrades without mandated upgrades for non-safety related functions.
B6	Support for development of programs and procedures and of professional state and local building staffing to effect LRMs.
B7	Support for dislocated tenants during seismic retrofit programs.
B8	Continued research directed at reducing costs for seismic construction, both new and existing.
B9	Continued work to incorporate a geotechnical component into model seismic codes.
B10	Continued research into development of codes that emphasize property damage control and maintenance of function over and above critical life-safety protection.

Supporting elements B3 through B5 support LRMs applicable to existing construction. B3 involves definition of seismic retrofit criteria and state legislation in order to make retrofitting cost-effective and feasible at standards more realistically below those required by current model seismic provisions and supports LRMs 10, 11, 12, 13, 14, and 15). B4 provides (through state legislation or local ordinance) for limitations on liability of local jurisdictions and their building officials overseeing a seismic retrofit program. This action supports LRMs 10, 11, 12, 13, 14, and 15. B5 provides for the development of legislation, etc., to facilitate seismic upgrading without triggering costly mandatory upgrades for non-safety-related functions (in support of LRMs 10, 11, 12, 13, 14, and 15).

B6 supports all building practice LRMs by providing federal funding for state and local governments in support of programs, procedures, and professional staffing (e.g., structural engineers, architects, inspectors) to effect LRMs. B6, like L10, may require federal assistance. This partial federal assistance may be warranted by reductions in contingent federal liabilities as a result of state and local activities and so may not be considered an additional burden on a federal earthquake insurance program. Consistent with this recommendation is that by Selkregg et al. (1984) for support for state-level commissions to oversee and encourage loss-reduction activities. Suitable representatives of private industry, including insurers, engineers, architects, and others engaged in loss-prevention activities, should be included on these commissions.

B7 addresses concerns identified in the stakeholder analysis by providing for inclusion of a social program to assist dislocated tenants during major seismic retrofit construction. Its inclusion as a supporting element derives from discussions by B. Zeidman at the project workshop and by Comerio (1989). In some instances seismic retrofit programs in seismic zone 4 may involve serious social dislocations. Examination of and minimization of these dislocations should be an integral element in these retrofit programs.

B8 recommends continued research efforts in order to reduce future costs of seismic design and retrofit. As our socioeconomic analysis confirmed, these costs are very significant factors in assessing the cost-efficiency of LRMs; even small reductions in costs for the LRMs proposed can have large-scale aggregate benefits.

B9 derives from cautions voiced at the third Advisory Panel meeting that one must not assume that the geotechnical component of LRMs for new construction is adequately covered in existing model building codes or in NEHRP provisions. Strengthening code concerns for geotechnical remediation of landslide, liquefaction, and subsidence sites and subdivisions, and continued progress in incorporating local high shaking relative site response factors into codes is important in assuring that sound landuse practices are buttressed by and often enforced in terms of sound building practices.

Status Quo Obstacles to Implementation of LRMs

Unfortunately, because of the many proposals that face them, key decision makers often make decisions simply in order to reduce the number of proposals remaining in their purview. (See Cohen et al., 1972, and March and Olsen, 1976.) Instead of evaluating each problem logically and searching for optimal solutions, decision makers are overwhelmed so that, fundamentally,

- o problems, solutions, and participants are seen as separate streams which flow through the system, and
- o system outcomes depend heavily on coupling the three streams in a timely fashion to take advantage of an opportunity for a decision.

In applying this approach to describe policy formulation in complex governmental organizations, Kingdon (1984) defined the three major process streams as

- o problem recognition,
- o formation and refining of policy proposals, and
- o politics.

Figure 4-1 presents a general illustration of the major elements contained in a model for assessing policy formulation, adoption, and implementation.

With respect to problem recognition, <u>risk analysis</u> has been the chief means discussed in this project to explain the extent to which earthquakes pose a problem. <u>Risk evaluation</u> has been used to answer critical questions related to social, technical, political, legal, and economic components of the problem streams. Inside advocates (i.e., policy entrepreneurs) who understand <u>risk results</u> and windows of opportunity will be able more fully to bring about an effective coupling of the problem, policy, and political streams. In other words, the process of risk and decision analysis, as discussed in Section 2.1, is essential to policy formulation, adoption, and implementation.

In the project workshop, participants indicated that LRMs facing the greatest obstacles to implementation are:

- o those pertaining to existing commercial/industrial/institutional structures and
- o those in smaller local jurisdictions (e.g., those with less financial, technical, and administrative capacity to effectuate LRMs),

Additional barriers already discussed include

- o disincentives to mitigate hazardous publicly owned buildings when 75 percent of all disaster costs are borne by the federal government in a Presidentially declared disaster and
- o disincentives to mitigate when insurance rates are insensitive to cost-effective mitigations.

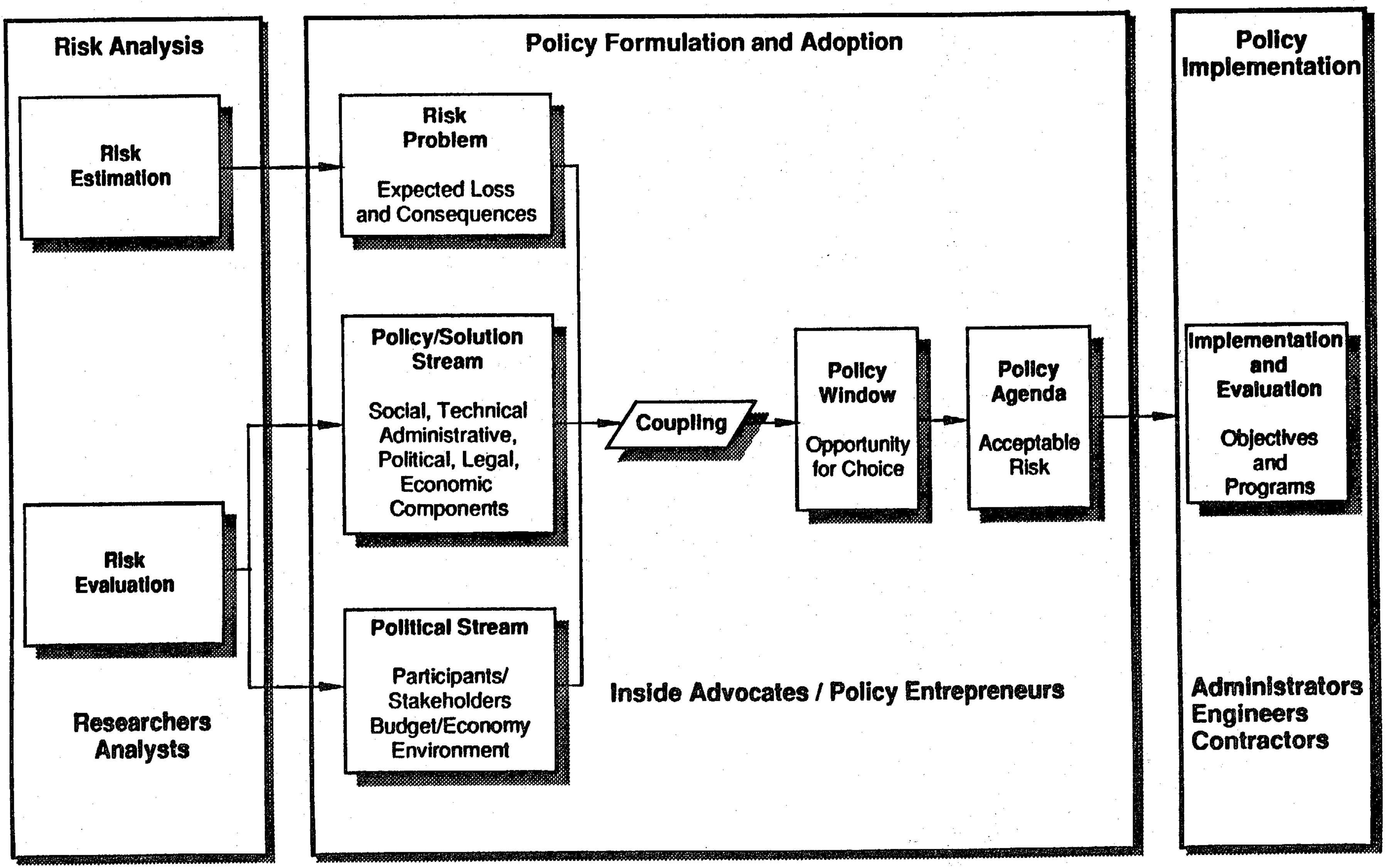

Figure 4-1. A Risk Management Model for Assessing the Process of Policy Formulation, Adoption, and Implementation

Means to overcome barriers faced in the process of implementation LRMs for natural hazards include:

- o identifying, mapping, and classifying natural hazard zones and estimating earthquake losses so as to clarify the extent of the risk and facilitate LRM implementation,
- o creating procedures and data bases to facilitate benefit-cost analyses,
- o reducing significant differences among model building codes in order to provide consistency among municipalities,
- o increasing technical capacity among local planning and building regulation departments,
- o developing political constituencies to support LRM implementation, and
- o understanding the short-term focus in decision-making so as to maximize efforts within the political system.

Workshop participants also proposed strategies to increase implementation success. These include:

- o making LRMs acceptable to the largest number of people and interest groups in the community,
- o creating advocacy groups within professional code organizations to support code changes,
- o having federal staff work with ad hoc committees of code organizations to facilitate the adoption of LRMs,
- o promoting simple code provisions for one-to-four family residences, and
- o promoting education/training programs to improve seismic design and construction practice.

Workshop participants emphasized linkage of earthquake insurance rate-structuring programs to those insurance programs for other perils. They also emphasized the integration of programs for public buildings, disaster relief, and insurance.

4.5 Summary

The stakeholder analysis highlighted the fact that current disaster relief and other federal policies constitute disincentives to state and local governments in implementing loss-reduction measures. Lenders benefit both from implementation of cost-effective mitigations and increased volumes of earthquake insurance purchase. Under current circumstances, federal taxpayers may benefit from implementation of mitigations for public construction even to the extent that federal cost-sharing programs may be considered cost-effective. Providing these cost-sharing programs will make benefit-cost ratios for state and local mitigations of public buildings more attractive. (See Appendix D.)

Using the results of the socioeconomic analysis, the Project Workshop participants, including the Advisory Panel and other project reviewers, and the project team were able to synthesize and further develop the fifteen LRMs that were recommended for inclusion in a federal insurance program. These fifteen LRMs affect all regions of the country. They emphasize new construction in seismic zones 2, 3, and 4 and existing construction in seismic zones 3 and 4. They emphasize landuse practices in seismic zones 3 and 4. All LRMs may be considered community-based in that key loci of enforcement lie in state and local governments. In effect, the fifteen LRMs can be incorporated into potential **earthquake ordinances**. For a particular community, details of earthquake ordinances would be defined by the seismic zone (i.e., 0, 1, 2, 3, and 4) of the community in question in conjunction with those LRMs in Tables 4-1 and 4-3 applicable to the zone. In a federal program there is a need for model earthquake ordinances. The fifteen LRMs developed in this report provide adequate guidance for ordinances which would be cost-effective and acceptable.

Project Advisory Panel members, workshop participants, reviewers, and the project team also developed supporting elements for these promising LRMs, and strategies for overcoming status quo obstacles to implementation of these LRMs. In the majority of cases, these supporting elements would have low costs relative to a national program. Higher costs might be involved in federal assistance and cost-sharing programs for training and staffing and for phasing or retrofitting potentially hazardous public buildings. In Section 5, we maintain that some of the higher costs of supporting promising LRMs may be justified with reference to programs specifically targeted to reduce existing contingent federal liabilities owing to disaster relief policy and other federal statutes.

5.0 LOSS-REDUCTION MEASURES IN VARIOUS FEDERAL INSURANCE CONTEXTS

In Section 3 we evaluated candidate loss-reduction activities in terms of their cost-effectiveness. In Section 4 we discussed fifteen promising LRMs which could serve to define earthquake ordinances.

Our goal in this section is to determine how LRMs may be incorporated into a federal earthquake insurance program. In achieving this goal, we define only general types of federal earthquake insurance constructs. Fuller definition and evaluation of possible constructs is beyond the project scope. Similarly, in order to show that it is feasible to incorporate LRMs into federal earthquake insurance involvements, it is necessary only to indicate some of the ways in which these LRMs may be so incorporated. Although we indicate that some federal earthquake insurance constructs would be incompatible with the LRMs proposed here, an administrator of a federal earthquake insurance involvement may devise ways other than are illustrated here in order to incorporate LRMs.

In Section 5.1 we present an overview of the possible roles that the federal government could play in the provision of disaster insurance and the application of loss-reduction measures.

In Section 5.2 we first discuss the <u>status quo</u> which involves no federal earthquake insurance program, and suggest how recent modifications and developments of disaster relief policy affect the implementation of loss-reduction measures.

In Section 5.3 we examine how the rate structure of an earthquake insurance program will affect the implementation of such LRMs as those recommended in this report.

In Section 5.4 we examine LRMs in a **primary** federal earthquake insurance context. We consider two general types of primary programs: (1) purchase of federal earthquake insurance made possible by federal agreements with local (or state) governments and (2) purchase of earthquake insurance without requiring such agreements. We assume that this earthquake insurance may be available only to some segment of the population (e.g., the residential section) and that private insurance markets will cover remaining segments.

In Section 5.5 we examine LRMs in a secondary federal earthquake insurance context.

Sections 4, 5.2, and 5.3, provide coherent programmatic directions for implementing LRMs into a federal insurance program. In general,

(1) existing contingent federal liabilities, themselves created to meet genuine state and local needs, justify increased federal influence over seismic construction and land-use planning processes, and

(2) in primary and secondary federal earthquake insurance programs, some of this influence can be effected through rate-making and/or pricing which ensures that buildings in higher risk categories are rated in accordance with their risks or that insurance availability is conditional only on LRM implementation and/or enforcement of earthquake ordinances. As previously explained, these ordinances do not place significant burdens on state or local governments in lower seismic zones, especially zones 0 and 1. Furthermore, public and selected private nonprofit buildings may be required to purchase earthquake insurance.

The loss-reduction programs outlined here emphasize reductions in expected long-term earthquake losses; they do not (and could not) include mechanisms to reduce significantly large-scale earthquake losses in the very near term. We address the issue of near-term losses only briefly in Section 5.1, where we indicate schematically how a federal earthquake insurance involvement with a mitigation element can assist in controlling losses from potential near-term large-scale earthquake disasters. We do not examine whether or not such an involvement yields the best or optimal system; however, a federal earthquake insurance and/or reinsurance system with a loss-reduction component can address both short-term and long-term losses associated with earthquakes.

5.1 Possible Federal Involvement in Earthquake Disaster Insurance

One principal reason for federal involvement in an earthquake insurance program is to protect the integrity of the United States economy. In this regard, we are referring to an expected catastrophic earthquake resulting in losses that could exceed fifty billion dollars. Another major objective is to reduce expected property and injury/life losses through the application of LRMs which can be implemented through an insurance mechanism.

Federal Insurance as Buffer

The functional role of federal insurance mechanisms and LRMs are illustrated in Figure 5-1. Federal involvement would serve as one component in a buffer zone of private and public entities which can take steps to reduce negative social, political, and economic impacts of a catastrophic earthquake. Within the buffer zone, state and local governments may require LRMs such as building codes to reduce structural damage, may provide self-insurance against future disasters, or may provide disaster relief. Private insurance companies may issue disaster policies to protect structures. The federal government may seek to

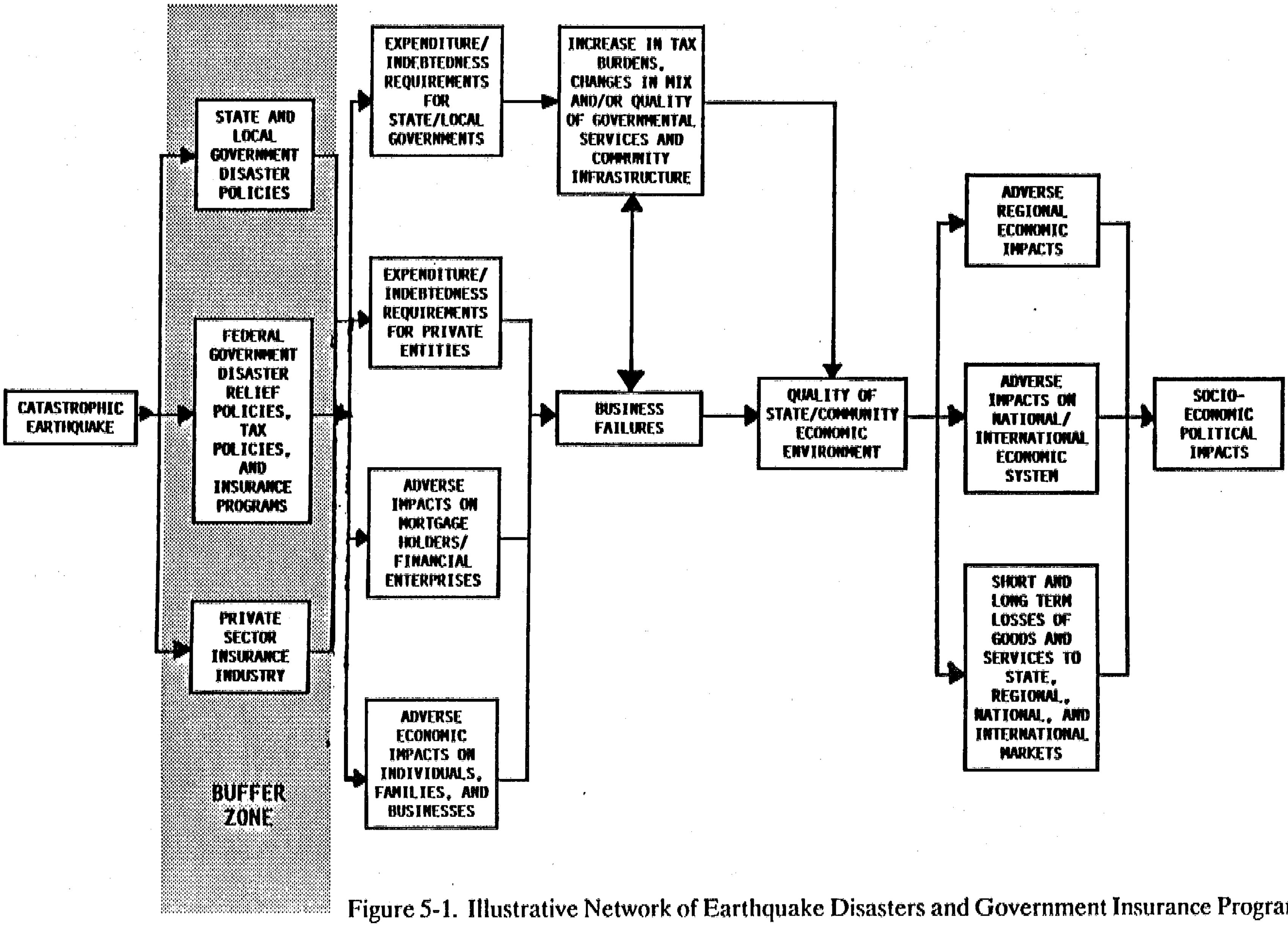

Figure 5-1. Illustrative Network of Earthquake Disasters and Government Insurance Programs

achieve LRMs through improved landuse and building practices and may provide insurance or disaster relief. Depending on the aggregate insurance coverage provided and disaster relief allowed, there will be inversely corresponding effects on the socio-political-economic system.

If there is insufficient insurance coverage and/or limited disaster relief, then the economy will be adversely impacted. State and local governments, private entities, financial institutions, or individuals may suffer severe primary losses, which in turn lead to business failures and long-term losses of goods and services throughout the system. Through a domino or ripple effect, secondary or higher order losses may equal or exceed primary losses.

It is common to think of insurance as a transfer mechanism which shifts risk from one party to another and of LRMs as a mechanism to reduce the risk to both the insured and the insurer. In the case of catastrophic disasters, insurance has the additional role of reducing the risk of financial crisis or collapse throughout the United States, because it reduces adverse primary impacts and thus buffers the system against secondary disruptions.

Possible Roles

There are at least **three roles** which the federal government could play in an earthquake insurance program. The first role is that of a **primary** insurer providing first-loss coverage through a government insurance policy. In Figure 5-2, this function is represented by box 4. This role could be accomplished in a manner similar to the National Flood Insurance Program or may take an alternative form. When the federal government works in cooperation with the private insurance industry (Figure 5-2, box 5) to issue policies and collect premiums, the linkage between the two entities is strong.

The second role which could be taken by the federal government is as a **reinsurer**, providing insurance coverage to the industry who compose the primary insurers (Figure 5-2, box 7). Again, the alliance of federal and private insurance shown in boxes 8 and 9 represents the combined effect of providing insurance coverage.

The third role would be for the federal government to provide a **combination of primary insurance and reinsurance**. How extensive federal involvement might be would be determined after evaluating the capabilities of private insurers and the necessary amount of insurance needed to protect against severe socio-political-economic impacts.

In the case of public and private nonprofit properties currently covered by the Stafford Act, the federal government currently can be perceived as being a co-insurer with the state government and private nonprofit organizations when a Presidential disaster declaration is

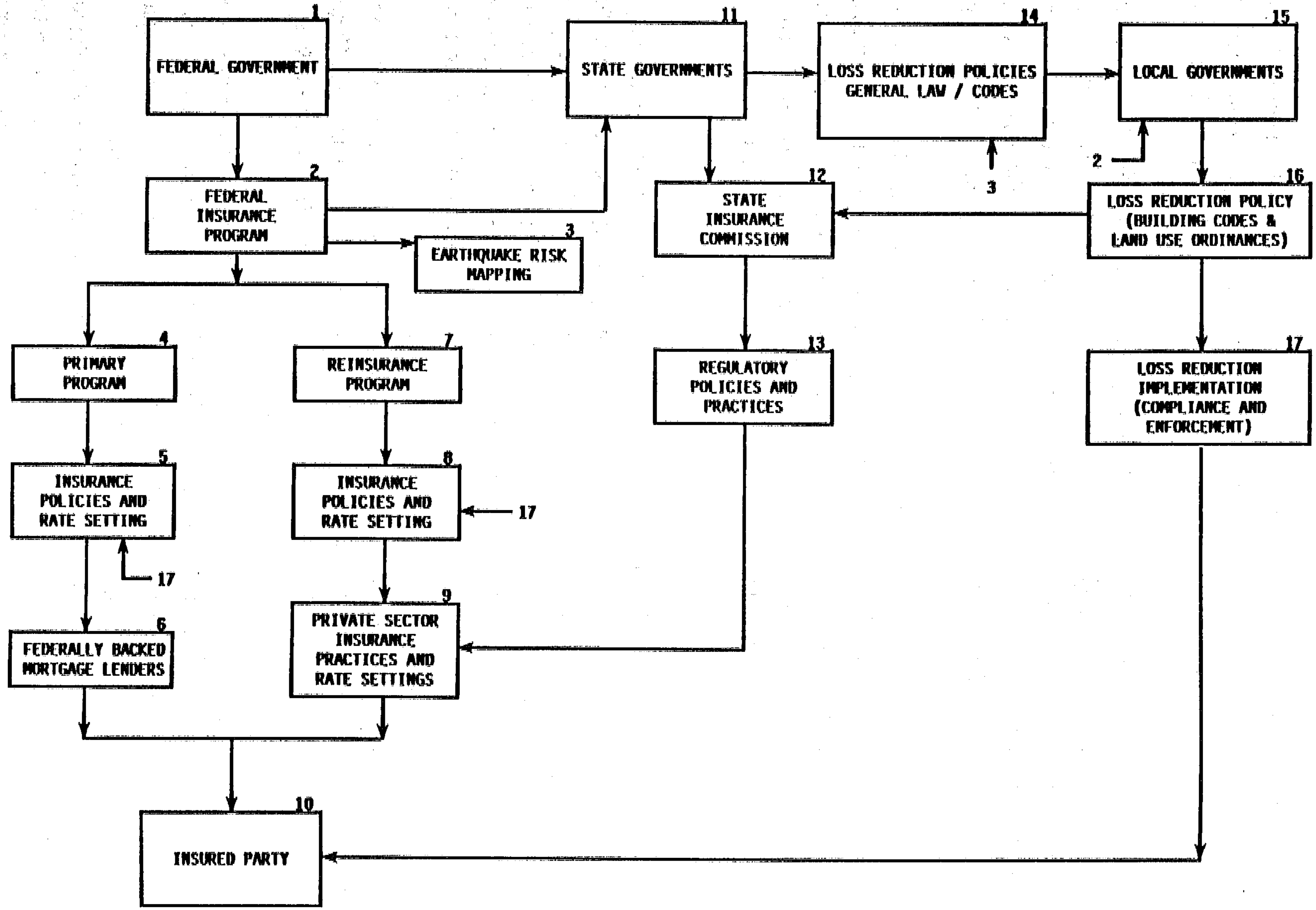

Figure 5-2. Intergovernmental-Insurance System

made. In Figure 5-1, this relationship is identified by the line connecting the federal and state boxes in the buffer zone.

In addition to providing insurance, federal involvement in requiring the implementation of LRMs would provide a means of risk reduction and thereby buffer adverse impacts in the society. While it has been demonstrated earlier in this report (Sections 3 and 4) that LRMs may be cost-effective and reduce risk, the enforcement of LRMs by local communities is not simple to achieve.

<u>Complexity of the Relationship between Federal, State and Local Governments and the Insurance System</u>

In order to view the role of federal insurance and LRM implementation from the proper perspective, it is important to understand the complex relationship between an intergovernmental regulatory system and an insurance market system. (See Figure 5-2.) The **intergovernmental regulatory system** is grounded in politics, and its purpose is ultimately to produce rules, regulations, and ordinances which benefit society -- in this case those mechanisms that reduce the risk of loss of property to earthquakes.

The intergovernmental aspects of this system are based on a constitutional form of government in which the <u>federal</u> government adopts laws that transcend <u>state</u> rule where most rights, including generally landuse and the development and construction of property, are guaranteed. Therefore, in its hierarchical relationship with states, the federal government may mandate rules or laws which are consistent with the constitutional system or may provide incentives to the states and/or local governments through the use of such instruments as grants-in-aid, loans, and sanctions, such as withholding or other forms of federal financial assistance.

<u>Local</u> governments, however, function at the pleasure of the states; therefore, the states may directly mandate that local governments engage in certain regulatory activities, or the states may pass through a federal requirement. The states may also provide incentives (such as cost-sharing) to accomplish the adoption and implementation of certain loss-reduction measures. It is important to note that the states can act directly without federal prompting. (E.g., in the case of California, the state legislature enacted the Field Act which gave the state authority over the design and construction of schools.) In spite of this ability of the state to require mitigation, as illustrated in Figure 5-2, **local governments retain, for the vast majority of buildings, primary responsibility for the adoption and implementation of loss-reduction measures for earthquakes by insuring compliance and enforcement.**

With respect to the **insurance market**, should the federal government decide to engage in the business of providing insurance, it may take on the role of a primary insurer or the role of a reinsurer. In either role, the federal government would be participating in the insurance market system, and thus would be working in cooperation with the insurance industry. In the case where the federal government provides primary insurance, it would have full control over the requiring of LRMs and the setting of rates.

In the case of reinsurance, the federal government would set rates for the sale of reinsurance to private sector companies, and those rates would be passed through to the insured parties. The federal government's relationship with reinsured parties would be largely contractual. The primary contractual relationships would be between the federal government and insurance companies, on the one hand, and the insurance companies and the insured parties, on the other hand. Effecting the implementation of LRMs through a reinsurance program would be more difficult, since federal relationships with state and local governments and with the insured are less direct than in a primary program.

In order to achieve the implementation of loss-reduction measures through the reinsurance program, the federal government would have to either mandate action or provide incentives to the states such that appropriate LRMs are adopted and implemented at the local level and then require that insured parties comply with the LRMs as implemented by local government. This compliance can be either mandated by the federal government through its ability to withhold insurance coverage or encouraged through an insurance rate-setting structure.

In effect, implementation of loss-reduction measures through an insurance program would be accomplished at the state level through a regulatory process on the part of the state through its insurance commission. The insurance commissioner of each state operates under the rules of the state, but establishes the specific set of regulations which govern the operation of the private sector insurance companies within the state. Therefore, the federal government could provide incentives to the state to require the private sector insurance industry to comply with incorporating loss-reduction requirements into the insurance market system.

In summary, it is important to understand that **the incorporation of loss-reduction measures in a national insurance program requires integration of a complex intergovernmental political system with an equally complex governmental insurance and market system.** The federal government has the ability to withhold insurance and to use the rate structure to enforce the adoption of certain LRMs; however, should local governments and/or states refuse to comply, the whole notion of having a federal insurance program to reduce the risk to the economic system of the United States fails. As a result, the federal government must work in both directions; it needs to work through the intergovernmental system as well as through the insurance market system to achieve the ends of incorporating loss-reduction measures which reduce the risk of loss and also providing insurance which reduces the risk of severe economic downturn in the event of a catastrophic earthquake. Thus, the federal government can and must use direct and indirect measures to achieve the adoption and enforcement of LRMs by local governments in high risk earthquake zones. This is a complex task, reflecting the characteristics of the political structure that we live and operate under.

Additional Challenges to Insurance and LRM Implementation

To achieve local compliance and establish a workable system, it is important initially that the adoption of loss-reduction measures be broadly accepted as necessary and desirable and as relatively noncontroversial. Even LRMs such as the requirement that minimum building codes be implemented within the various risk zones in the United States have met with strong challenges. Unfortunately, the challenges to incorporating LRMs involve additional issues and requirements which extend beyond these initial levels.

For adoption, compliance, and enforcement to take place there must exist sufficient constituency support, inside advocates, sufficient community resources, necessary technical skills, and jurisdictional acceptance (Alesch and Petak, 1986; Mittler, 1989; and Petak, 1984). In general, the smaller the jurisdiction, the greater the probability that one or more of these requirements will not be met (Mittler, 1989). In smaller communities, technical abilities are scarce, fiscal capacity is low, tax effort is minimal, data to make accurate decisions is limited, and the resources to generate sufficient amounts of data is low, organized constituencies (political interest groups) are unlikely, and the political dynamics of the community would largely be conservative in approaching implementation of LRMs. When a community is uninformed it is unable to attack a problem knowledgably and find worthwhile solutions, so it uses this lack of information as an excuse for inaction.

With respect to landuse practices, it has historically been difficult for the federal government to engage in regulating activities. There have been numerous attempts under laws established by the Environmental Protection Agency and the NFIP to engage in activities seen by many as national landuse planning. Project participants expressed extremely diverse opinions on the success of these programs. For both building and landuse planning acts, some project participants have questioned whether or not the federal government has a legitimate role to play. (See our response in Section 5.2.) Thus, the application of broad landuse control measures is controversial although we have some reasonably successful examples in the form of coastal zone management and floodplain and wetlands protection acts.

In the area of building codes, the United States operates with three generally accepted model codes which are applied in different regions of the country. They are not equal in their consideration of seismic design and construction. The seismic provisions for new buildings, prepared by the Building Seismic Safety Council under contract to FEMA, are gaining acceptance in BOCA and SBC as well as in ASCE standards.

Whatever the benefit to be gained by implementing earthquake-related damage-resistant measures in building construction and the rehabilitation of existing buildings and by the application of landuse measures, it must be large enough to be of significance in terms of the definition of catastrophe that we are concerned with when we talk about a national governmentally-sponsored insurance program. By our earlier discussion, we noted that the immediate aim of such a program is to protect the viability of the U.S. economic system in the event of a catastrophic earthquake. Therefore, at a federal level, catastrophe occurs when the state and local governments are unable to meet the demands brought about by the disaster event, in which case the U. S. economic system might be seriously harmed. The benefit, then, of LRMs is in reducing the consequences of that event and other events in terms of dollar loss.

In the very near term, the LRMs proposed here may not reduce the catastrophic loss potential enough to turn it into a noncatastrophe. LRMs are important because, in the long term, they may result in significantly reducing the probability of building collapse, mortality and morbidity and loss of personal property which could contribute significantly in terms of the ability to recover from a catastrophe, and they may assure that the level of potential losses associated with earthquakes does not increase significantly as the built environment changes and grows.

5.2 Status Quo Policy and its Implications for the Implementation of LRMs and the Purchase of Earthquake Insurance

In Section 1 we explained that current earthquake loss-prevention programs are fragmentary owing to the locus of control, various sources of building codes, lack of economies of scale (capital and skilled labor), the sporadic timing of earthquake policy development, insurance system considerations, the public "spillover" benefits of privately undertaken LRMs, and disaster relief system considerations. Specifically, we concluded that current federal and state disaster relief policies, viewed here only from the narrow perspective of their implications for loss-prevention programs

- o create contingent federal liabilities in the event of a presidential declaration of disaster (see Appendix C),
- o create inequities in federal funding through these liabilities (see Petak and Atkisson, 1982), and
- o create strong financial disincentives for state and local governments to engage in pre-disaster earthquake loss-reduction projects for publicly owned buildings (see Appendix D).

In this subsection, we discuss the possible implementation of LRMs within the limitations of status quo programs. For purposes of this discussion, the status quo is viewed as a collection of policy instruments currently available to implement LRMs. We provide a brief discussion of the current role of lending institutions in requiring earthquake insurance purchase. We then emphasize current disaster relief assistance and hazard mitigation policy as defined in the 1988 Stafford Act. Appendix D supplements this section with an illustration of stakeholder considerations for seismic retrofit of public buildings.

The Role of Lenders in the Status Quo with Respect to LRMs and Insurance Purchase Requirements

Studies by Brown and Weston (1980) and by Brown and Gerhart (1989) concluded:

- o that the property/casualty insurance industry would not aggressively market earthquake insurance voluntarily;
- o that the industry could be induced to provide widespread protection against earthquake damage by mortgage-finance industry demands that security property be protected by earthquake insurance;
- o that legislatively imposed requirements for such coverage can be an effective stimulus as A.B. 2865 demonstrated in California [though as Brown and Schiller pointed out (1979), legislatively mandated coverage may be vulnerable to constitutional challenge];
- o and that inherent in the implementation of any scheme for inducing widespread earthquake insurance coverage were risks of antitrust violation, especially with respect to insurers, although under the guidance of qualified counsel such risks could be identified and circumvented.

In California, judicial intervention (the Garvey case, overturned on appeal) extending the doctrine of "concurrent causation" stimulated counteractive legislation (A.B. 2865) which required all property/casualty underwriters doing business in the state to make a one-time offer to policyholders to sell them an earthquake endorsement. These offers resulted in a doubling, to about 20%, of California homeowners who were insured against earthquake. Arguably, the typical 10% deductible clause and the premium cost discouraged wider acceptance.

During the 1980s, there was general acceptance of the strong probability that a major earthquake would strike California within 20 to 30 years. The mortgage-finance industry's general response to any earthquake-related threat to the value of its security interest in mortgaged property was to ignore the prospect. Not even proximity to Alquist-Priolo "special studies zones" generated selectivity in evaluating loan applications.

The secondary mortgage-finance market, in those instances where it evidenced any concern, generally preferred direct purchase of portfolio protection to the alternative of requiring earthquake insurance as a condition of residential mortgage loans, even though such a requirement could have been imposed selectively, state by state, through a minor modification to standard-form Federal National Mortgage Administration (FNMA)/Federal Home Loan Mortgage Corporation loan documents. Loan originators, with a very few exceptions, ignored the opportunity to require earthquake coverage and registered strong opposition to tentative suggestions by FNMA that it might consider requiring primary lenders to include earthquake coverage for any loans assigned to the secondary market. Central to that resistance was the recognition that the cost of such additional insurance coverage could be a significant factor in the competition for borrower-customers in the absence of a demand universally imposed on all loan agreements. Since not all loans are sold into the secondary market, such universality could not be achieved. Geographical dispersion of security properties was also presumed to diminish portfolio risks of some but not all lenders, as was the incidence of wood frame shake-resistant residential structures.

In effect, within the status quo, lending institutions are not currently in a position to enforce LRMs. As suggested in Section 4, lenders would benefit from major program modifications that require LRMs and/or effect increased earthquake insurance purchase. Such program modifications would be needed for lending institutions to play a major role in implementing earthquake loss-reduction measures.

<u>Implications of the Stafford Act for Loss Prevention</u>

The Stafford Act offers a number of means to encourage and support loss-reduction efforts. Specifically, the Stafford Act

- o requires that currently "applicable codes, specifications, and standards" be used in federally assisted repairs or replacements (sections 406 and 409),
- o provides monies to support additional loss-prevention programs (section 404),
- o strongly suggests that a loss-prevention element become a significant feature of pre-disaster earthquake planning (sections 404 and 409),
- o may be interpreted to suggest that subsidies to state and local governments may be warranted to induce cost-effective LRMs for public buildings (see Appendix D), and
- o conditionally requires earthquake insurance purchase for public and private nonprofit buildings repaired, restored, reconstructed, or replaced with the assistance of federal disaster relief funds (section 311).

Hence, for damaged public and private nonprofit buildings, seismic replacement and retrofit can be required given adequate current codes, specifications, and standards. In effecting LRMs in this context, it is important that adequate codes, specifications, and standards be defined. In addition, with state insurance regulator certification, insurance purchase can be required for repaired or replaced buildings so that a large share of the contingent Federal liabilities for these buildings can be transferred to state and local governments (FEMA, March 1989, p. 11639). Issues pertaining to the certification by the state insurance regulator have not been addressed in this project.

LRM Implementation within Status Quo Policy as Defined by the Stafford Act

The types of loss-reduction efforts referenced in the Stafford Act accord with the types of LRMs that we have been examining in this project. These types include

- o structural hazard control or protection projects,
- o construction activities that will result in protection from hazards,
- o retrofitting of facilities,
- o acquisition of hazardous properties or relocation of facilities to less hazardous sites,
- o development of state or local mitigation standards (See for instance, supporting elements B3, B4, B5, in Table 4-4; supporting elements L7, L8, L9 in Table 4-2; loss-reduction measures in Tables 4-1 and 4-3.), and
- o development of comprehensive hazard mitigation programs with implementation as an essential component. (FEMA, May, 1989)

The process of identifying, evaluating, prioritizing, and monitoring these risk-reduction measures, as suggested by the Stafford Act, may be encapsulated as follows (see FEMA, Sept. 1989, p. 37957; FEMA, March, 1989, pp. 11649-53; FEMA, May, 1989):

- o Prior to the disaster, the state can develop a hazard mitigation plan, while the Federal government assists with model standards, codes, and specifications.

- o After the disaster, the state evaluates the hazards and prepares a new hazard mitigation plan, updates the existing mitigation plan so that it identifies and prioritizes LRMs for the state, as primary grantee under section 404, and for potential subgrantees (restricted in the FEMA, May, 1989 memorandum to state agencies, municipalities, certain private nonprofit organizations, and Indian tribes).

- o The federal government approves or declines project(s) and/or findings and/or makes suggestions as to the state hazard mitigation plan.

- o Once the plan is approved, the state monitors implementation of LRMs after the plan.

Criteria for inclusion of LRMs in the state hazard mitigation plan include

- o a cost-effectiveness test, which involves a 10 percent discount rate (FEMA, May, 1989, p. 14; OMB, 1972), and

- o determination of "best fit" in overall state or governmental risk reduction plan, and/or

- o determination that the consequences of not undertaking the LRM are severely detrimental, and/or

- o determination that the LRMs have the greatest potential impact on reducing future disaster losses. (FEMA, May, 1989).

The overall linkage between section 404 of the Stafford Act and LRMs proposed in this project suggests clarification of two elements of section 404:

- o the 10 percent standard for a discount rate to be used in determining "cost-effectiveness" and

- o the legally allowable and politically feasible scope of the types of building usages to which section 404 can be applied.

If the 10 percent standard is used, and dominates all other criteria for identification and selection of LRMs, then many of the LRMs identified in Tables 4-3 and especially those in Table 4-1 will probably fail to be deemed "cost-effective." In this case, <u>as a rule</u>, only those LRMs passing Tier 1 criteria will likely be properly deemed "cost-effective". They include:

- o use of geotechnical techniques to minimize severe liquefaction and/or subsidence hazards in seismic zone 4 for commercial and public developments, and large-scale residential tracts,

- o retrofit of unbolted and/or poorly anchored wood-frame residences in seismic zone 4, and

- o adoption of, compliance with, and enforcement of adequate seismic codes.

On a project-by-project basis, a number of other LRMs, such as anchoring/securing critical equipment in specific buildings, may be found to be cost-effective. If, however, the 10 percent rule is one of the criteria to be weighed, and life-safety and long-term disaster reduction considerations are given significant weight, then Tables 4-1 through 4-4 are helpful in considering LRMs to be used along with their supporting elements.

If the scope of facilities covered under section 404 is deemed to be the same as the scope of facilities covered under section 406, then only those LRMs apply that pertain to publicly owned (and in special cases, private nonprofit) buildings. These include applicable portions of all landuse LRMs in Table 4-1 and applicable portions of B1, B2, B4, B5, B6 and B7 in Table 4-3, along with requisite supporting elements.

Obstacles to Implementation within the Framework of the Status Quo

We have interpreted the Stafford Act as implying that:

- o Hazard mitigation planning processes, both before and after earthquake disasters, can be augmented to include cost-effective LRMs and/or earthquake ordinances (and also supporting elements as defined in Section 4).
- o Federal funding assistance for repair or replacement of damaged public and selected private nonprofit buildings can include monies that recipients can use to meet current seismic standards.
- o There is an urgency to define standards and measures for seismic repair of existing buildings as a basis for clarifying "applicable codes, specifications, and standards" to be used in federally assisted repairs.
- o Monies may be provided for developing risk-reduction programs after an earthquake. The earthquake ordinances proposed in Section 4 suggest general LRMs for the implementation of such programs.
- o Projects federally financed for repairs should be required to purchase earthquake insurance.

In effect, the 1988 Stafford Act modified previous disaster relief programs to encourage loss-reduction activities in post-earthquake circumstances. Pre-earthquake hazard mitigation planning should now benefit from the expertise of those in earthquake building and landuse disciplines. Hazard mitigation policies and programs developed after earthquakes should reflect loss-reduction elements such as those defined in Section 4.

In spite of these positive implications of the Stafford Act, because the federal government pays at least 75 percent of the cost of post-earthquake recovery, federal disaster relief inherently discourages property loss-reduction programs for state and local and selected private nonprofit buildings. As previous sections and many project participants have affirmed, the minimum 75 percent recipient cost share remains a formidable obstacle to the implementation of LRMs for public buildings not yet affected by an earthquake disaster (see Appendix D). With the post-disaster orientation of current policies, risk managers of public and selected private nonprofit buildings have in effect free "coinsurance" policies (with the Federal Treasury serving as a retrocessional reserve fund -- one paid by future taxpayers after the damage has occurred). Yet cost-effective LRMs for public and private nonprofit buildings benefit the public in a great many ways. Lives can be saved, injuries can be reduced, and governmental and educational downtime can be minimized. Public buildings could serve as models for seismic design rather than as examples of poor construction and ill-considered retrofit. This general approach is consistent with Executive Order 12699 of January 5, 1990, which applies similar reasoning to all new construction of buildings to be leased for federal uses or purchased or constructed with federal funding assistance.

From a general liability standpoint, the federal government has a clear interest in state and local programs that affect potential earthquake losses, including those pertaining to development, adoption, and implementation of seismic loss-reduction measures, including landuse and building practices. These controls were constructed in the federal system owing to genuine needs at state and local levels for federal disaster assistance. We must conclude that current federal controls over earthquake losses are inadequate relative to contingent federal liabilities incurred. This suggests that stronger (i.e., commensurate) controls are needed over these federal liabilities, whether they be through subsidies, altered tax deduction policies, or federal earthquake insurance involvement.

Summary

Section 406 of the Stafford Act may serve as a useful hazard reduction tool for publicly owned and private nonprofit buildings damaged by an earthquake in a Presidentially declared disaster. Continuing development of standards, specifications, and codes, especially for buildings and sites in seismic zones 3 and 4 for retrofits, and seismic zones 2 and 3 for new construction, are essential to sound public policy. The requirement in section 311 of state insurance regulator certification for earthquake insurance availability, adequacy, and necessity greatly qualifies possible assistance in relieving federal liabilities for these damaged buildings, once they are retrofitted, relocated, or replaced in accordance with adequate standards. Earthquake insurance purchase can limit future disaster assistance to portions of the population who are not or should not have been insured.

Section 404 promises to encourage earthquake risk reduction efforts, especially if life-safety and other community criteria are weighed heavily and public programs to assist residential/commercial/industrial loss-reduction measures are encouraged or allowed. However, in the face of funding restrictions after a major disaster, and in face of pressures to confine loss-reduction projects to public buildings and selected private nonprofit buildings, section 404 may in practice be more restrictive and require considerable judgment. LRMs proposed in Tables 4-1 and 4-3 serve as useful guides to community-based programs and LRMs that passed at Tier 1 suggest the sorts of projects that will likely be cost-effective.

The Stafford Act also modifies the way in which pre-disaster planning can and should occur. Pre-disaster planning should now contain a very strong loss-prevention element so that post-disaster recovery activities can benefit from this element. Otherwise, post-disaster implementation of section 404 will have the extreme disadvantage of requiring hasty reports which are not supported by prior activities. (See Spangle, 1987.) Tables 4-1 through 4-4 provide guidelines for activities that should be undertaken prior to disasters. Monies currently earmarked under the Stafford Act for pre-disaster planning appear to be inadequate for the professional labor required to engage in loss-prevention planning and execution. Moreover, since this planning and execution requires consideration of many stakeholders, relative autonomy of functions from existing agencies may be needed so that monies used for loss-prevention are not spent on other activities, or overwhelmed by the powers of other state and local agencies.

The presence of a large federal cost share for public and nonprofit buildings damaged by disasters has many implications. For example, even with the Stafford Act, federal controls over loss-prevention activities are not commensurate with potential federal liabilities incurred. These potential liabilities apply not only to public and selected private nonprofit buildings but to homeowners, small businesses (through the SBA loan program), and to mortgages generally (through federally backed mortgage programs). Liabilities with respect to health, life, safety, and environmental matters also exist. As a consequence of these existing potential liabilities, the federal government has a clear interest in such activities as

- o the state and local governmental adoption of, enforcement of, and compliance with building codes,
- o life, safety, and welfare issues,
- o mortgage-default issues, and
- o low-income housing issues.

Unfortunately, current federal disaster assistance policy tools provide inadequate means to achieve broad scale implementation of LRMs because they are mandated only in localities declared federal disaster areas by the President. Instead of being proactive and supporting the implementation of LRMs prior to earthquake events, the current disaster policy is reactive and triggered by unusual events. The Stafford Act, therefore, is not by itself a policy that is capable of preparing the entire United States for a catastrophic earthquake.

The principal goal of current disaster policy is to ensure that economic stability be restored in the affected disaster region. While necessary to support recovery efforts, the current policy has no provisions to address primary and secondary effects in areas other than Presidentially declared disaster areas. Thus, by itself, current policy is insufficient to deal with the full impacts of single disasters.

As currently written, the Stafford Act mandates that communities affected by disasters employ loss-reduction measures to reduce the risk from future disasters. These measures are not standardized; they are location-specific. In addition, they are politically negotiated by state and federal officials rather than designed by mitigation specialists, and then they are amassed in a Hazard Mitigation Plan early in the recovery process rather than well-formulated prior to the disaster.

In order to protect the United States from a catastrophic earthquake, the current disaster policy is clearly insufficient. What is needed is a mechanism which prepares the country for disasters and guarantees that excessive loss of life and injury and severe economic downturn are avoided.

Because federal controls over these existing concerns are not commensurate with liabilities potentially incurred, significant program alterations could be made in order to strengthen these controls. In Sections 5.3 and 5.4 we shall examine how major program interventions involving federal earthquake insurance may augment these controls. However, at present and barring significant federal legislation to augment these controls (such as through altered taxation deduction policy), **we suggest that a program of federal subsidies to public and selected private nonprofit entities, including universities, be initiated to undertake cost-effective LRMs as a means to reduce these potential federal statutory liabilities.**

5.3 Insurance Rates and Loss-Reduction Measures

Before considering how LRMs might be incorporated into the two major types of federal earthquake insurance program constructs (primary or secondary insurance), we must look at one major incorporation issue -- how the rate structure of any earthquake insurance program will affect the implementation of such LRMs as those proposed in this report. The compatibility of the LRMs proposed here with federal earthquake insurance involvement may largely depend on how rates are differentiated on the basis of such key factors as seismic hazards and building vulnerabilities. Consistent with the use of partially risk-based rates as a public policy instrument would be the decision to permit federal earthquake insurance for all properties on the condition that cost-effective LRMs be undertaken. Hence, a major issue facing the administration of a federal earthquake insurance program will be the degree to which the rate structure supports and sustains cost-effective LRMs. Considerations of how this major issue fits into primary and secondary federal earthquake insurance involvements are discussed in Sections 5.4 and 5.5.

In a review of the fifteen LRMs proposed, one finds the following factors emphasized:

- o seismic zone designations (0, 1, 2, 3, and 4), with special emphasis on higher risk zones,
- o current model seismic codes as indicators of building performance in earthquakes,
- o potentially hazardous buildings in seismic zone 4,
- o one- and two-family wood frame dwellings in seismic zones 3 and especially 4, and
- o severe liquefaction, landslide, subsidence, surface fault zones, and high shaking amplification sites in seismic zones 3 and 4.

Because this report emphasizes community-based LRMs, these factors are not rare. (See Section 3.2.) These factors do not as a result reflect the full range of scientific and engineering considerations that **could** be examined in an **extremely thorough** seismic analysis of an individual building. As indicated in Eguchi et al. (1989), costs of very detailed investigations have rapidly diminishing returns with respect to rate development for all but very expensive properties, properties with large numbers of occupants, very high potential business interruption costs, or critical community functions. As a consequence, **a fully risk-based rating system -- one that satisfies the highest level of scientific and engineering precision and thoroughness available for all buildings -- would be prohibitive in cost**. The partially risk-based rating system implied in this report lies between the two extremes -- a fully risk-based system with cost-prohibitive underwriting expenses and a flat or relatively flat rating system with extremely low underwriting costs. Only the above factors are of concern in the partially risk-based system recommended.

For this reason, we shall speak of various partially risk-based rating systems -- as opposed to flat rates. Rates may be flat relative to some factors but not to others, and the factors of interest in this report are those reflected in the LRMs proposed.

There are several important reasons for considering some risk factors in the rating structure. Summarily, these reasons are that:

1. For the most cost-effective LRMs, all other things being equal, actuarially risk-based rates are adequate economic inducements for undertaking the LRMs.
2. Even if all things are not equal, flat rates with respect to parameters reflected in LRMs can be counterproductive to efforts to implement these LRMs.
3. In at least some cases costs of incorporating partially risk based rates are characteristic of current prudent underwriting.
4. In a federal earthquake insurance involvement severe administrative problems can be avoided if mapping for LRMs converges as much as is feasible with mapping for insurance rates.

The following discussion illustrates the first three reasons with respect to the very simple building parameters ("highly damageable" versus other) and seismic zones parameters (especially seismic zone 4) reflected in the building practice LRMs. The fourth reason has been discussed already in Section 2.

Economic Inducements

The economic inducement for implementing LRMs can be seen first in the wide variations of risk levels and rates reflected in some current rating systems and secondly as reflected in our socioeconomic analysis of the LRMs themselves. The fact that rates currently are not perceived as providing incentives to LRMs reflects primarily the extreme business cycles that earthquake insurance undergoes (as discussed in Section 1.2 and in Cheney and Whiteman, 1987). During soft markets, actual rates may be extremely competitive. As the market hardens, rate increases may occur even for parties who undertake LRMs. The hardened market -- resulting from limited reinsurance availability and higher reinsurance prices -- makes rates even less sensitive to LRMs undertaken.

For **commercial structures** no dispute exists over the wide variations in earthquake insurance rates currently applied to diverse building vulnerability classes. According to Steinbrugge (1982, p. 372), rates across building classes vary more than tenfold. (Rates for class 1C and 2A buildings are approximately 10 percent of rates for class 5C buildings.) Rates across residential building classes vary to a slightly lesser extent. To indicate the significant spread of risk among various building categories (all other factors being equal), we have developed an analysis described in the footnote below.[1] Appendix B contains adequate materials for a preliminary actuarial analysis of potential rate differentials, as illustrated in Appendix C and also with finer detail in terms of general procedures outlined in the footnote below.

For **residential construction**, our socioeconomic analysis suggests that there is sufficient spread of risk for differentiation of rates by class of construction -- especially in higher seismic zones. Use of the best class of construction as a means of determining rates would imply a subsidy situation for those types of structures expected to contribute significantly to expected future losses. In some cases, cost-effective retrofits for these structures are available.

Risk-Based Rates as Incentives

Given the extreme differences in risks for various building classes, differences sufficient to make LRMs cost-effective, then all other things being equal, actuarially sound rates are sufficient economic inducements for undertaking LRMs. With actuarially sound rates, the difference in risks between the status quo and the implementation of the LRM is magnified in rates through the use of a loading factor. This loading factor, a multiplier, represents minimal administrative costs including overhead marketing, claims adjustment, underwriting costs and fees, if any, plus costs to cover catastrophic factors (see Section 2). Since costs for

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1. For residential construction and for illustrative purposes, we have modified SEISRISK-III (Bender and Perkins, 1987) in order to provide comparative annualized average loss for various types of residential construction. A composite attenuation function developed by N. Donovan was used along with soil factors derived from Evernden (1985) and with intensity conversion factors derived from Trifunac (1976). Residential loss algorithms used in this project are summarized in Appendix B of this report. Of chief interest are those average annual losses derived for

- o unanchored and unreinforced wood frame dwellings,
- o anchored and reinforced wood frame dwellings,
- o low-rise unreinforced masonry dwellings, and
- o residential construction without specific seismic design (seismic zone 0 or 1)

We find that throughout California, average annual losses for unanchored and unreinforced dwellings exceed those for anchored and reinforced dwellings by a factor of almost three. Average annual losses for unreinforced masonry units exceed those for anchored and reinforced wood frame dwellings by a factor of approximately seven. Using Wiggins' (1986) algorithms, we find that average annual losses for residential construction with no special seismic design exceed those for residential construction designed to UBC seismic code 3 standards by a factor of almost five. These findings do not reflect differences in strong ground motions throughout California.

LRMs are unaffected by rates, then the benefits of undertaking the LRM are multiplied by this factor if these benefits are reflected in rate differentials. In other words, if the present value of the future stream of expected benefits is B, then the present value of the future stream of expected premium reductions is L x B, in which L is the loading factor exceeding unity. So, if the benefits (B) exceed the costs (C), then the premium reductions (i.e., L x B) in a risk-based system exceed the costs by an even greater margin. Hence, LRMs considered cost-effective without respect to rate differentials prove to be even more cost-effective if rates are suitably risk-based.

The above reasons apply only if "all other things are equal." As already indicated, earthquake insurance markets currently do not have sufficiently stable prices for owners to discern clearly that undertaking LRMs results in rate reductions. Also, as indicated in our socioeconomic analyses of state and local buildings, where much of the risk is assumed by the federal taxpayer, risks may be "externalized" and thus do not serve as an incentive to implementing LRMs. (See Appendix D.) Furthermore, not all benefits of LRMs accrue to building owners. Some benefits, for instance, may accrue to building tenants through resulting increased life-safety protection and less chance of prolonged business interruption losses. Other benefits, for instance, may accrue to lending institutions, through reduced likelihood of losses resulting from default. These "spillover" effects, or benefits to others, will not necessarily be reflected in actuarially sound partially risk-based rates. Another reason why partially risk-based rates do not always induce LRMs is that people do not always behave in economically rational ways, even if they have pertinent information and can interpret it correctly.

<u>Flat Rates as Disincentives</u>

Our second reason for strong consideration of partially risk-based rates is that even if these rates do not in all cases induce LRMs, flat rates will serve as disincentives to the implementation of LRMs, even for new developments. Flat rates provide potentially subsidized economic protection against earthquake damage. For instance, if rates are flat in California, then owners in a lower seismic zone will be subsidizing owners in high liquefaction and landslide susceptible sites along the coast and in higher seismic zones. Likewise, owners of buildings designed to current adequate code standards will be subsidizing owners of buildings that are highly damageable. In effect, flat rates would provide financial protection against earthquake-related damage whether or not seismically-responsible landuse and building practices were employed.

In a voluntary earthquake insurance program using flat rates, numerous cases of moral hazard may result. Owners of highly damageable properties, knowing that rates are subsidized, will insure; owners knowing that their rates subsidize risks assumed by others will refuse to insure. Moreover, given the protection of earthquake rates subsidized by others, those with higher risks will not be economically induced to reduce those risks. Whatever motivations exist for individuals, firms, municipalities, and states to undertake LRMs, they will not include rate reductions, and the presence of subsidized earthquake insurance will serve as a disincentive to reducing expected property damage. Benefit-cost ratios for LRMs that are otherwise favorable may become unfavorable given insurance protection provided by flat rates. (See Appendix D.)

Current Underwriting Practice

The third reason supporting the contention that partially risk-based insurance premiums are to be strongly considered is that risk-based rates are characteristic of prudent underwriting practice. Continuing the current practice of many earthquake insurers, these rates would reflect

- o seismic zone designations (or, in other terms, macroseismicity estimates of earthquake sources, their rates of seismicity and attenuation functions), and
- o building vulnerability categories (here, with a minimum distinction between highly damageable commercial and residential construction on the one hand and other construction on the other hand).

To a lesser extent some insurers currently consider

- o high site amplification, liquefaction, landslide, subsidence, and fault zones.

The feasibility of including such site hazards into earthquake insurance considerations is currently being examined in conjunction with studies under California legislation SB1885.

Additionally, the cost of differentiating structures into broad-based categories is not necessarily so great as may be presumed. Inspectors at time of sale may be able to determine whether or not dwellings are bolted to their foundations. Age of structure and type of exterior construction may also serve as proxies for rating categories. Sampling techniques can be used to assess the quality of data derived from telephone calls and other data sources. Prudent insurers writing both residential and commercial structures currently include such considerations in their underwriting practices. These considerations are important to them in order to control losses from their insured exposures. Moreover, rate credits can be considered for owners who prove, contrary to prima facie ratings, that their structures are not higher risks.

Current underwriting practice reflects both information costs and private insurance market competition costs. From a business standpoint, insurers need rate differentials at least in order to assure that lesser risks do not purchase insurance elsewhere. Insurers with fairly flat rates might be faced with worse risks at rates which do not adequately cover these risks. However, a governmental insurance program, especially if primary and mandated, may avoid such problems of adverse selection because both low and high risks are included. Also to be considered are governmental objectives including providing affordable insurance both in the short- and long-term and decreasing risks to property, persons, and financial and institutional entities. In such a monopolistic setting, where normal competitive business considerations do not apply, underwriting costs of partially risk-based rates may be erroneously conceived as additional administrative burdens -- resulting in higher overall rates -- rather than as means to achieve primary program objectives, including loss-reduction and resulting long-term reductions in rates. These considerations show that, in a fuller study of federal earthquake insurance issues, the objectives of a governmental insurance involvement need to be considered, especially if competitive market concerns are largely or fully removed.

Conclusions

In summary, administration of a federal earthquake insurance involvement will require strong consideration of the types of rates involved, and how they affect such LRMs as those proposed in this report. We maintain that a partially risk-based insurance rate-setting system, sensitive to regional seismic strong motion hazards, and, in higher seismic zones (especially 3 and 4) to differences in building vulnerabilities and site conditions is one of two major vehicles (the other being earthquake ordinances) for incorporating LRMs into a federal earthquake insurance program. To the extent that rates do not reflect the diverse types of risks reflected in the fifteen LRMs proposed here, rates will be counterproductive to the implementation of those LRMs. Perfectly flat rates -- as an extreme example -- would undercut economic arguments for undertaking LRMs, since insurance could protect economic investments in high-risk properties at rates that were subsidized by those with lower risks.

Even if partially risk-based rates do not induce LRMs, they provide at least some incentive for mitigation. For instance, if it costs $2,000 to bolt a dwelling to the foundation, then a homeowner has some incentive to mitigate if the premium is thereby reduced by over one hundred dollars a year. But, the homeowner has little or no economic incentive to do so if premiums are the same whether or not dwellings are bolted to their foundations. In fact, flat rates could be used as a reason to oppose any public policy measures that encourage very cost-effective property loss-reduction measures, including code compliance and retrofitting. Thus, in the administration of a federal earthquake insurance involvement, one significant consideration will be the degree to which the rating system supports and sustains the LRMs proposed here.

These reasons thus provide extremely powerful considerations for partially risk-based rates in order to incorporate LRMs into a federal earthquake insurance program. The administrative ease of having partially risk-based rating maps that coincide with LRM maps greatly contrasts to the administrative difficulties of extreme differences between these rating and LRM maps. This project supports only modest underwriting costs to incorporate partially risk-based rates. The misconception that the costs for developing risk-based rates will be a burden on a primary mandated (i.e., monopolistic) federal earthquake insurance program needs to be further examined in a fuller study addressing the feasibility and program objectives of federal earthquake insurance. In estimating the cost-effectiveness of a federal earthquake insurance involvement, benefits of loss-reduction must also be included.

5.4 Loss-Reduction Measures in a Primary Federal Earthquake Insurance Program

This subsection includes a general discussion of those aspects of a primary insurance program that are pertinent to LRMs. We deal principally with logical features of a primary program and in no way define precise details of that program.

Potentially Increased Federal Liabilities and Rate Considerations

If the federal government undertakes a primary earthquake insurance program with respect to some or all classes of private owners and tenants, potential short-term federal liabilities will be increased. **To offset both short- and long-term potential liabilities,** premium payments could be used to develop a pre-disaster reserve fund. Also, programs that induce loss reduction (as for public and selected nonprofit buildings) could potentially reduce these liabilities. Deductibles may be increased or limits of liability may be decreased. For instance, if there is strong desire for low deductible levels, then premiums must be increased, or some other mechanism (e.g., subsidies) must be employed to cover potential increased federal liabilities.

General mechanisms for **decreasing earthquake insurance rates** (i.e., making them more affordable) without increasing deductible levels and without adversely affecting LRMs can include

- o long-term and uniform implementation of adequate seismic building standards,
- o long-term and uniform implementation of adequate seismic landuse and geotechnical standards and criteria,
- o developing greater geographic distribution of insured properties, and
- o pooling perils.

These mechanisms suggest

- o the long-term desirability of inducing uniform and adequate seismic construction and landuse planning/geotechnical standards and criteria,
- o the desirability of strong inducements and/or requirements to assume greater geographic spread of seismic risks, and
- o the desirability (if feasible) of integrating perils and, to the extent politically acceptable, of cross-subsidizing among perils and among geographic regions for earthquake.

Providing very affordable rates (i.e., low premiums, low deductibles, high limits of liability) is initially an attractive inducement for voluntarily assuring geographic distribution of earthquake insurance purchase. To do so, however, a program may have to be subsidized in the event of earthquake losses <u>except with respect to buildings for which contingent federal liabilities are already significant</u> (e.g., public and selected private nonprofit buildings).

In this report, we have not argued against subsidies in general, especially those that serve as investments in reducing future earthquake losses; however, subsidies for poor construction do not serve to reduce future losses and should be assumed with caution. (Early subsidized rates in the NFIP were heavily criticized as noted in Neil Fulton, 1984, Monday and Butler, 1984, and Kusler and Bloomgren, 1984.) As suggested in Section 5.3 (and with caveats for the various types of subsidy situations that can arise), providing lower rates for more damageable buildings and higher risk sites by subsidizing with rates from lower risks can be counterproductive to implementation of loss-reduction programs. Greater affordability in rates should be achieved through such risk diversification methods as pooling risks and encouraging geographic spread of coverage, which promote rather than hinder loss-reduction programs.

The apparent **tension between affordable rates and LRMs** is less dramatic than may be supposed. Nonetheless, the administrator of a primary federal earthquake insurance program will need to make difficult decisions regarding the degree to which the rate structure supports and sustains the LRMs proposed here. Even if rates are lowered in response to implementation of LRMs, they may not be perceived by consumers to be affordable, and for some low-income segments of the population, insurance purchase may be viewed as a financial hardship. As suggested in section 5.3, there will be a temptation in a non-competitive situation for administrators to reduce underwriting costs incurred in the private market setting, and so to discourage safe construction and landuse practices in order to reduce -- temporarily -- rates. The point here is that while many social, political, economic and legal considerations on rates charged may enter into administrative decisions, those decisions must not ignore the potentially deleterious effects of having lower risks subsidize higher risks, particularly those for which cost-effective LRMs are available. The administrative weaknesses of maintaining and applying radically diverse maps for LRMs and insurance rates further supports the contention that both maps should be risk-based.

General Linkages with the NFIP

Discussion of a definitive linkage between the NFIP and a primary earthquake insurance program lies beyond the scope of this project. However, the general logic and experience of the NFIP are useful in terms of implementing loss-control measures in a primary federal earthquake insurance program.

Major distinctions between flood insurance programs and potential earthquake programs derive from mapping considerations. Large-scale mapping of local areas forms the primary basis in the NFIP for flood plain management and rating programs. In contrast, macrozonation (e.g., seismic zones as illustrated in Figure 2-5) currently forms the basis for the most thoroughly developed earthquake loss-reduction programs, namely, those that deal with seismic code development, adoption, compliance, and enforcement. This distinction is reflected in the primary emphasis of this report on LRMs and rate development relative to those parameters of importance in the LRMs proposed: macrozones, seismic building vulnerability categories, and, in higher seismic hazard zones (3 and 4), local seismic hazards. Current evidence supporting the cost-effectiveness of landuse LRMs is significantly weaker than evidence supporting the cost-effectiveness of building design and construction LRMs. Hence, there is less emphasis in this project on the very large-scale maps (at scale larger than 1:24,000) that are characteristic of such detailed landuse efforts as in the NFIP.

Earthquake hazard microzonation may eventually evolve to take on a greater significance as applied and theoretical research improves our understanding of the geotechnical environment and ability to employ larger-scale mapping techniques cost-effectively. Structural engineering, geotechnical engineering, architecture, and other building construction advancements would be priorities along with risk analysis that emphasizes risk assessments and regional mapping rather than very large-scale mapping. These are the principal methods to achieving loss reduction which would be applied under a primary earthquake insurance program.

Nevertheless, the overall logic and experience of the NFIP provides a basis for understanding the sort of program that a primary federal earthquake insurance program could become and the various ways in which it may evolve. The basis for the national flood insurance program is an agreement between communities and the federal government that communities will adopt, comply with, and adequately enforce flood plain management ordinances. Noncompliance entails possible suspension from the program or rate surcharges. Participating communities who comply enable individuals or corporations whose insurable property is located within the community to purchase flood insurance. As support for this program, FEMA/FIA has mapped special flood hazard area zones at large scales and has gradually made rates less subsidized and more actuarially sound. Problems of noncompliance, although rare, have been recognized and are being addressed. (See FEMA/FIA, July 1989, p. 29668; FEMA, June 1989; and ISO, 1989.)

In the early years of the NFIP (1968-1973) even highly subsidized rates did not make flood insurance purchase attractive to property owners. Under the Flood Disaster Protection Act of 1973, purchase became required in special flood hazard zones for those property owners assisted by Federal programs or Federally supervised, regulated, or insured agencies or institutions. Hence, lending institutions were called on to require that flood insurance be purchased by their borrowers whose security consisted of building properties located in special flood hazard zones. Lenders may at their discretion require that flood insurance be purchased by borrowers with securities in properties located outside special flood hazard zones where to date approximately one-third of claims paid have occurred. Both residential and commercial property is included, but land values are not insured. (FEMA/FIA, July 1989).

The Coastal Barrier Resources Act, Public Law 97-348, prohibits the NFIP from providing flood insurance protection for structures built or substantially improved after October 1, 1968, in areas designated undeveloped coastal barriers. For these areas, as in other areas where flood insurance is unavailable, federally backed lenders may make conventional loans at their own discretion. FEMA/FIA has recognized problems of compliance of mortgage lending institutions with regulations, but continues to work on resolutions. Similar experience and progress has occurred with respect to defining limits of liability coverage -- a problem that arose for residential condominiums initially treated as multi-unit residential buildings and more recently treated as single-family units (FEMA/FIA, July 1989).

Thus, the NFIP is working out the problems as they become apparent in the application of rules and regulations in the program. The agreement with local governments constitutes a voluntary means by which community-based standards can be implemented through local governments. Agreements with insurers in the Write-Your-Own (WYO) program suggest precedents whereby government-insurer relationships can be clarified, especially with respect to how insurers can act as agents for the federal government.

We did not assess whether or not voluntary community participation in a primary federal earthquake insurance program would provide adequate geographic spread of coverage to reduce rates significantly. However, if a primary earthquake insurance program were developed along these lines, then the LRMs proposed in Tables 4-1 and 4-3 would fit in well. Informally, these serve to define generally earthquake ordinances (earthquake resistant standards) analogous to flood plain management ordinances. So developed, earthquake LRMs have the advantage of being able to be incorporated directly into overall community programs. The ordinances as envisaged here primarily emphasize building loss-reduction practices. As microzonation practices evolve and possibly become incorporated into seismic building codes in the next decade or two, the linkage between landuse planning and building loss-reduction practices may become closer. As with the NFIP, a major federal role would involve developing earthquake insurance rates. This may eventually include very large-scale mapping, but initially would currently involve smaller scale regional mapping along with assessments of building vulnerabilities and regional seismicity. The community orientation of LRMs in Tables 4-1 and 4-3 fits well into a primary federal insurance program involving agreements between the federal government and local governments. The possibility of earthquake-induced flooding and mudslides, a topic excluded from consideration in this project, itself suggests linkages between the current NFIP and potential primary earthquake insurance involvements.

A contrasting primary program structure may be one in which the sole primary relationship is between the federal government and the insured. Such a program permits insurance companies to act as agents for federal insurance. In this type of primary earthquake insurance program, we shall assume as before that the federal government has a primary responsibility for rate-making. Since this type of program may require only an indirect relationship between the federal government and communities, no direct federal controls over LRM requirements are available. Thus, it is unlikely that LRMs will be initiated, unless they are induced by differential insurance rates or by insurance availability requirements.

A potentially expensive program, from an underwriting standpoint, would involve considerable federal guidance in determining rates for various communities so that rates would reflect risk. This would not entail federal-community agreements but could involve considerable efforts to rate buildings. One means to effect this rating system would be to presume that higher rates apply and to place the burden of proof on the buyer to substantiate any request for rate reductions/credits. A potentially less expensive alternative would be the generation of federal-community agreements acknowledging that earthquake risk-reduction ordinances (such LRMs defined in Tables 4-1 and 4-3) were in effect. These are potentially less expensive because uniformity of loss-reduction and underwriting standards could be assured.

Possible Extension of Provision (d) of Section 406 of the Stafford Act

One possible remedy for the inadequate tools currently available to control contingent federal liabilities lies in extending provision (d) of section 406 of the Stafford Act to include primary earthquake insurance. In effect, justified by the need to reduce current federal liabilities, one could require that public and selected private nonprofit buildings purchase earthquake insurance (at partially risk-based rates) as a condition of receipt of federal disaster assistance. Section 311 currently requires this earthquake insurance purchase only with state insurance regulator certification of availability, adequacy, and necessity. If this earthquake insurance purchase requirement were made conditional only on receipt of federal disaster assistance, provision (d) of section 406 then would indicate that noncompliance with insurance purchase entails that federal disaster relief is reduced by the amount of insurance proceeds that would otherwise have been covered by earthquake insurance.

This large step in a primary federal earthquake insurance program would need to be justified, as is done here, by reference to existing contingent federal liabilities and the inadequacy of current controls over these liabilities. State insurance regulators would need to be involved in discussions of such program changes. To buttress this program, we suggest as before possible federal subsidies for cost-effective seismic retrofits and other seismic program developments, including staffing assistance. Existing federal liabilities can be reduced through a program that specifically addresses potential cost-effective LRMs and supporting elements.

As Appendix D clarifies, sanctions are not the only effective means to encourage LRMs. Implementation of this program element may require additional staffing and training to assure that public and private nonprofit buildings are rated appropriately and that rate credits are provided for suitable seismic mitigation activities. Extremely affordable rates may also be warranted <u>but only for construction that satisfies programmatic guidance developed</u> in Tables 4-1 and 4-3.

It is undecided here as to whether or not this extension should be part of the primary or the secondary federal earthquake insurance program. It is possible that the private insurance industry, regulated by state insurance commissions, could adequately rate these buildings and supply earthquake insurance given secondary federal insurance involvement.

Conclusions

This discussion has suggested the following general conclusions:

- o Partially risk-based rates are desirable for the building usages covered in the primary program (and a strong *prima facie* case exists against rates for riskier buildings that are subsidized by other lesser risks -- unless undertaking LRMs is a condition for earthquake insurance purchase).

- o Partially risk-based rates form a primary basis for a federal program in which insurance is provided directly to owners and tenants.

- o In order to lower rates on an actuarial basis (whether through decreased premiums, decreased deductibles, or increased limits of liability), risk diversification is desirable, whether through geographic spread or through linkage with other perils (see Section 2.2).

- o In order to minimize potential conflicts between LRMs proposed here and those federally supported elsewhere, and in order to use the experience of current primary federal insurance programs, there should be a linkage with the National Flood Insurance Program (NFIP). (This does not entail a single administration over the two programs, nor does it imply that the federal earthquake insurance structure should be modeled after the NFIP. However, this does entail using benefits of program experience, including legal experience, and examination of advantages and disadvantages of linking flood and earthquake perils, along with other perils, if any, for which there is market failure.)

- o In the early stages of the NFIP, the subsidized rates for risky facilities were heavily criticized; and a strong case can be made that more damageable buildings and more hazardous sites for which cost-effective LRMs are possible should not be subsidized through lower rates in a federal earthquake insurance program having a loss-reduction element.

- o If the primary program involves a direct optional agreement between communities and the federal government, then the LRMs proposed in Tables 4-1 and 4-3 can serve generally to define for local and state governments an "earthquake ordinance" (a set of earthquake-resistance standards) for participation in the primary program; Tables 4-2 and 4-4 define supporting elements (see caveats and additions in following discussion). Earthquake ordinances pertaining to building usages covered in the primary program are compatible with a program involving federal agreements with state or local governments.

- o If the primary program involves direct relationships between the federal government and local residents, and no agreement with the local government, then indirect means can be used to induce LRMs for public buildings, including
  - o rate credits for buildings identified as not being potentially hazardous on the condition that LRMs for public buildings are implemented,
  - o federal assistance to state and local LRM programs and projects, and
  - o earthquake insurance purchase requirements for public and private nonprofit buildings.
- o Given current contingent federal liabilities for private and nonprofit buildings, consideration should be given to extending provision (d) of section 406 of the Stafford Act (covering mandatory flood insurance purchase and commensurate decrease in federal post-disaster obligations with noncompliance) to incorporate earthquake as well as flood insurance considerations. (An analogous recommendation appears in French and Rudholm, 1990.)

Thus, a primary federal earthquake insurance program can serve as a strong policy tool to encourage LRMs for buildings covered under the program. However, a primary program by itself does not provide strong inducements for LRMs for buildings not covered. LRMs for public buildings may be induced by federal cost-sharing programs or by providing selected rate credits. Hence, inclusion of LRMs for public buildings can be justified with reference to existing contingent federal liabilities without regard to those additional liabilities incurred by federal earthquake insurance involvement.

In a primary federal earthquake program, then, an administrator has two basic possible tools for incorporating LRMs: partially risk-based rates and earthquake ordinances. An administrator may also justify LRMs for public buildings with respect to non-insurance-related existing contingent federal liabilities. Thus, it is clearly feasible to incorporate LRMs into a primary federal earthquake insurance program.

5.5 Loss-Reduction Measures in a Secondary Federal Earthquake Insurance Program

The preceding sections provide a general overview of how major federal program changes or additions can provide greater controls over LRMs. The need for greater controls over implementation of LRMs is supported by (a) existing contingent federal liabilities and (b) contingent federal liabilities that would be created under a primary program. More generally, it is in the ordinary interests of the federal government to be concerned with the national welfare, which includes the financial stability of institutions and the health and well-being of citizens.

As a consequence of existing federal liabilities, we have maintained that federal assistance for cost-effective LRMs may be suitable especially in those cases where these subsidies can help to reduce contingent federal liabilities. We have further maintained that risk-based premiums or premiums conditional on LRMs being undertaken may be desirable to support LRMs proposed in Section 4.

The challenge of incorporating LRMs into a secondary program, or a combined primary and/or secondary program, is enormous. In this subsection, we examine some features of such programs.

Key Relationships

Figure 5-3 provides a very schematic account of some key relationships within a secondary federal program. The figure is designed to address the critical question of how LRMs are to be enforced in a secondary earthquake insurance program. Key participants of interest are the federal government, insurers, the insured, state insurance regulators, lenders, and communities. We examine these various participants and their general relationships in order to understand how to incorporate LRMs into a secondary program.

Owing to the competitive nature of private financial institutions, we do not propose to use the leverage of lending institutions as a direct means to incorporate LRMs into a secondary program. As indicated in Section 5.2, federally-backed lending institutions may not be eager to require purchase of earthquake insurance. Although some lending institutions may be strongly supportive of implementation of LRMs, others may be less supportive. Hence, whereas lending institutions may be helpful in ensuring broader insurance purchases and in influencing the implementation of LRMs, we do not regard them as primary enforcers of LRMs. For similar reasons, we have not treated insurance companies as primary enforcers of LRMs even though they may lobby communities to achieve adequate or superior seismic standards. As a result of competitive pressures to avoid cases of adverse selection, private insurers may use partially risk-based rates based on available information on risks, and this may assist indirectly in encouraging LRMs. Nevertheless, business considerations including the desire for profitability will dictate the degree to which risk-based rates are used, and the practice will vary considerably among private insurers.

State insurance regulators are in a good position to begin requiring that insurance companies provide the federal government (and private reinsurers) with adequate information on which to base rates and to assess potential liabilities.

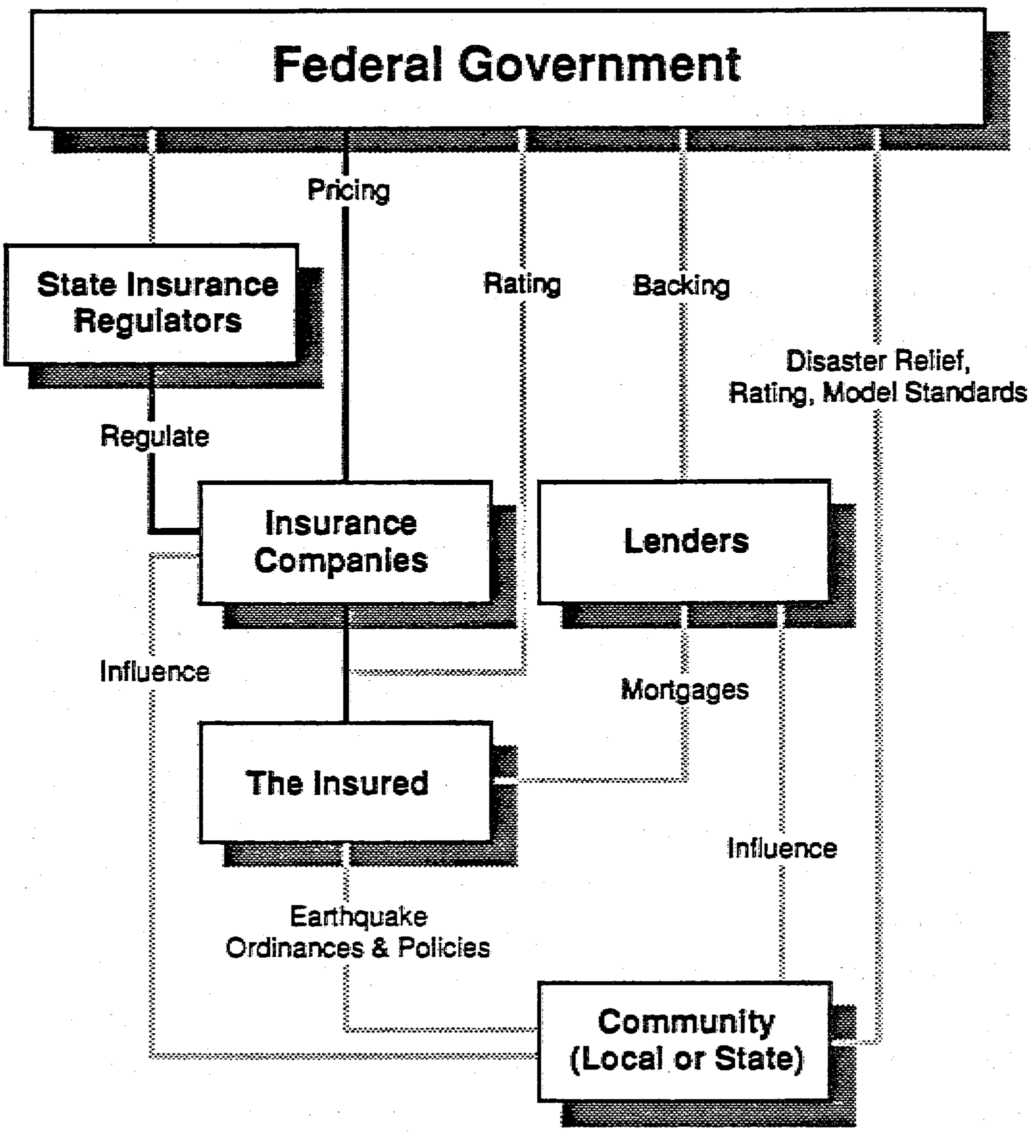

Figure 5-3. A Simplified Diagram of Probable and Possible Relationships in a Secondary Federal Insurance Program

(Shaded lines denote possible relationships.)

Pricing Mechanisms and LRMs

One way to effectuate partially risk-based rates in a secondary system is for the federal government to form cooperative relationships with state insurance regulators. Secondary earthquake insurance would be made available to various states conditional on state insurance regulator assurance that rates would be reflective of those seismic risk factors pertinent to the fifteen LRMs proposed here and discussed in Section 5.3. Hence, on this alternative, state insurance regulators would assume the responsibility for ensuring that rates are partially risk-based in the sense used throughout this project. We do not here elaborate on the pros and cons of this alternative, but merely mention it as one conceivable administrative avenue for making a secondary federal earthquake program insurance involvement compatible with the LRMs proposed.

The pricing mechanism for earthquake reinsurance is sufficiently complex and entrenched that it may require many years for this mechanism to be adjusted to ensure that LRMs are being incorporated through at least partially risk-based rates. Another administrative alternative for ensuring this incorporation would be to develop secondary prices to reflect primary risks. The justification for federal control over this secondary pricing lies in the liabilities potentially incurred by taxpayers if the federal government becomes a secondary earthquake insurer. In developing secondary prices, the administrator would need to require

- o that insurance companies writing earthquake policies and desiring federal earthquake reinsurance provide exposure data as means to evaluate secondary prices, and
- o that risk estimation methods such as those indicated in Section 2 (and in greater detail in Eguchi et al., 1989, and Taylor, Hayne, and Tillman, 1990) be used to develop prices for this reinsurance.

The first step would be extremely large since

(a) primary earthquake insurance portfolios may change on a day-to-day basis (so that standards for aggregating portfolio exposures would be needed);

(b) adequate exposure data, such as building structural vulnerability categories, currently are not always collected by primary insurers, especially when policies are written that cover a great many sites. Collection of these data may be regarded as a nuisance by many underwriters; and

(c) suitable analysis of these data, given private reinsurance arrangements, deductibles, and limits of liability, can be time-consuming unless simplified guidelines are provided that are nonetheless compatible with secondary pricing to reflect primary risks.

Hence, use of secondary pricing to reflect primary risks is an available tool, although difficult to implement, to assure that a secondary federal earthquake insurance involvement is compatible with the LRMs proposed here. In a fuller analysis of this second alternative, consideration should be given to the extent to which in a secondary earthquake insurance program there can be confidence that participating primary insurers, in a competitive market, will necessarily and uniformly use partially risk-based rates. The degree to which insurers will use such rates to remain competitive may bear on the degree to which raw exposure data are needed for secondary pricing.

A third alternative, once considered the most promising, would be to have the federal government develop primary rate guidelines. We regard federally prepared guidelines as a much more direct approach to inducing LRMs than attempts to affect prices only at the secondary level. Many underwriters may balk at the tedium and time required to collect and transmit this exposure data, and the timeliness of data for secondary pricing decisions may require considerable systematization of raw data. In contrast, with federally prepared guidelines, direct rates can be guided so that the total volume of sales by underwriters can provide an index of the relative risks within their portfolios and, hence, an index of the residual risks borne by the federal government as a secondary insurer.

Moreover, the federal government could provide for rates relative to community LRM standards (earthquake ordinances) that have evolved and that are in effect. Through this mechanism, greater uniformity in rate-making could be achieved, since community-level earthquake risk assessments would in the main dictate how facilities are to be rated. In addition, rate advantages could be provided for owners and tenants in communities that incorporate LRMs. Finally, the federal government could ensure that subsidized rates are not provided for potentially hazardous buildings or highly damageable structures.

This third alternative -- direct federal control over primary rates -- may receive challenges owing to state jurisdiction over insurance regulation. Hence, although initially promising, the desire not to create federal-state conflicts makes this a less attractive alternative.

A fourth alternative, possibly combined with the others, is to use the leverage of a combined primary-secondary federal earthquake insurance involvement (if this combined program exists) in order to assure that LRMs are initiated in states and municipalities for which earthquake insurance is made available. In effect, federal earthquake insurance availability would be made conditional on earthquake ordinances being implemented by state and local governments. Analogous considerations were developed in Section 5.4 when insurance purchase requirements for public buildings were discussed. By itself, the availability of federal earthquake insurance involvement may not suffice to induce communities to adopt earthquake ordinances. If combined with other programs, such as federal assistance programs suggested in Section 5.2, then this fourth alternative may prove to be useful. Moreover, serious consideration should be given as to whether or not the secondary pricing mechanism supports and sustains the earthquake ordinances.

We have examined at least four possible ways in which secondary federal earthquake insurance involvement may be compatible with the LRMs proposed. These four ways suggest that it is feasible -- although challenging -- to incorporate LRMs into a federal earthquake insurance involvement. In all four ways, partially risk-based rates (or else rates conditional on LRMs being undertaken) are a major vehicle for supporting and sustaining the LRMs proposed here. The expression "incorporate" suggests that federal earthquake insurance involvement can be seriously inconsistent with implementation of LRMs, and that the incorporation issue partially turns on how to make fiscal incentives consistent with implementation of LRMs. The first and second alternatives, for instance, stress these financial incentives. The fourth alternative stresses direct enforcement of cost-effective LRMs at the community level.

Conclusions

In this subsection we have developed the following conclusions:

- It appears to be feasible, although extremely challenging, to incorporate LRMs into a secondary federal earthquake insurance program.
- As part of a combined primary and secondary program, if one exists, various reasons may be provided for applying LRMs to all buildings rather than merely to those buildings as covered in the primary program. Particularly, the administrator may use other contingent federal liabilities to justify extension of LRM requirements to buildings covered in a secondary program. (These may include existing liabilities or others created under a primary program.) These reasons, while not fully compelling, nonetheless should be strongly considered by program administrators.
- One very direct way to assure that rates are compatible with LRMs is for the federal government to control rate-making and conditions of insurance availability (e.g., by requiring that insurance is available on the condition that LRMs are undertaken). Although this way is clearly feasible in a primary federal earthquake insurance program, it encounters large-scale obstacles in a secondary federal earthquake program to the extent that such federal controls over direct rate-making may challenge, or appear to challenge, state controls over insurance regulation.

- o One less direct way to assure that rates are consistent with LRMs is to develop prices at a secondary level to reflect primary risks. This way, although feasible, would be extremely challenging and would require changes of habits among many primary earthquake insurers.
- o Another way to assure that rates are consistent with LRMs is to make insurance availability conditional on state regulation that assumes partially risk-based rates (through a cooperative arrangement with state insurance regulators so that they may assure that primary rates reflect risks). This way is mentioned here to indicate that various administrative programs may be conceivable, although not without possible problems and challenges.

Thus, as in a primary federal earthquake insurance program, the administrator of a secondary program has two vehicles for incorporation of LRMs: partially risk-based rates and earthquake ordinances. However, in a secondary federal earthquake insurance involvement, influence over requiring both LRMs and partially risk-based rates will be less direct and to that extent more challenging. The presence of private insurer competition that leads to the frequent use of partially risk-based rates in order to avoid adverse selection may mitigate some of the challenges faced by an administrator over a secondary federal earthquake insurance program.

These conclusions were arrived at through an examination of a few of the key participants and relationships within a federal program. There is no examination here of the overall political feasibility of the above conclusions or of the details of any secondary federal earthquake insurance construct. With respect to a combined primary and secondary federal earthquake insurance involvement, it follows from the foregoing conclusions that significant federal responsibility for or involvement in encouraging directly or indirectly partially risk-based rates will be a common element of both programs. As indicated previously, if the major thrust of this encouragement is to ensure that potentially hazardous or highly damageable buildings in regions of higher seismicity are not provided rates subsidized by lower risks, then the costs of underwriting these rates will not be extraordinarily high and will continue current practices of many earthquake insurers. If rates are tied to community standards that have evolved over the years (or that in many regions of the country have remained uniform), then underwriting costs will be reasonable.

5.6 Summary of Approaches to Incorporating LRMs into Various Federal Insurance Contexts

In overview, the overriding goals of a federal earthquake insurance program are:

- o to indemnify persons for their losses in the event of future earthquake disasters,
- o to reduce the tragic losses of life and increasing losses of property from earthquakes,
- o to ensure financial stability throughout the United States should a large catastrophic earthquake occur in the near term and
- o to sustain this stability through efforts which control direct expected losses and hence secondary, tertiary, and higher order losses.

The latter is the goal of this report. The costs of physically modifying the built environment in order to reduce very significant losses from a large catastrophic earthquake in the near term would be exorbitant. Hence, the LRMs recommended here reduce expected losses in the long term.

In the status quo, disaster relief policy designed to serve many social and political needs nonetheless serves as a disincentive to the implementation of loss-reduction measures for public and selected private buildings. (See Burby et al., 1990.) The significance of existing federal liabilities justifies increased federal controls along with possible cost-sharing, training, and education programs. Earthquake ordinances as defined earlier can assist in prioritizing funding under section 404 of the Stafford Act and in defining where increased controls are most useful.

With increased federal liabilities in a primary and/or secondary earthquake insurance program, we maintain that the federal government would need to have direct influence over rating at the primary level and/or pricing at the secondary level. These controls and influences are needed to assure that partially risk-based rates are employed. These partially risk-based rates are here encouraged chiefly for economic and administrative reasons, but they also offer potential life-safety and other benefits. Residents of communities that adopt earthquake ordinances can also receive rate credits in a primary earthquake insurance program.

We have addressed generally how the loss-reduction measures proposed in this report can be incorporated into a federal earthquake insurance program. Incorporation of LRMs involves two major vehicles:

(a) their use in defining earthquake ordinances for implementation at state and local levels, and

(b) the use of or encouragement of partially risk-based rates (or else availability of insurance only on the condition that LRMs are undertaken).

To facilitate incorporation, we propose federal legislation to implement loss- and hence deficit-reducing seismic mitigation programs for public and selected private nonprofit buildings. These programs would provide training, staffing, and other supporting elements needed to implement LRMs within a federal earthquake insurance program.

In a primary federal earthquake insurance involvement, both vehicles -- ordinances and partially risk-based rates -- could be used to promote LRMs. In a secondary federal earthquake insurance involvement, less direct means (including secondary pricing to reflect risks and the use of the leverage of other programs) would need to be used to incorporate LRMs.

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APPENDIX A
BIOGRAPHICAL SKETCHES OF ADVISORY PANEL MEMBERS

Richard J. Roth, Jr., Co-Chair

Richard J. Roth, Jr., was appointed to the position of Assistant Insurance Commissioner and Chief Property/Casualty Actuary, State of California, on July 1, 1984. Roth joined the Department of Insurance as a property/casualty actuary in March, 1981.

He is responsible for issues relating to property and liability insurance, specifically reinsurance, workers' compensation, medical malpractice, mortgage guaranty, public liability, commercial, and the availability and affordability of automobile insurance. He is the author of the Department's annual report on earthquake insurance. As the Chief Property/Casualty Actuary, Roth is involved in issues of solvency, financial reporting, and the actuarial portion of the financial examination of property/casualty companies.

Roth is a Fellow of the Casualty Actuarial Society and received a Bachelor of Science in Mathematics in 1964 and Masters degrees in Economics and Statistics in 1970 from Stanford University. He also holds a law degree and is a member of the Connecticut State Bar. Prior to entering the insurance profession, he was an aeronautical engineer for six years.

D. Ward, Co-Chair

A licensed architect, Del Ward currently is a consultant in building technology and also serves as an adjunct faculty member in the Graduate School of Architecture, University of Utah. In both capacities, his principal work pertains to building technology and structural systems.

Architectural education has been the predominant activity of his career. He began his teaching career at Columbia University, New York City, in 1958. From 1960 to 1975 he was a Professor of Architecture at the University of Utah. After that he joined the State University system of Florida for two years, where he assisted in organizing the Florida Solar Energy Center, and energy research center. Since 1981 he has engaged in private architectural practice and consulting.

His involvement in architectural aspects of seismic design spans a period of more than twenty years and a number of activities, beginning in an academic research setting. From 1977 to 1981, he was executive director of the Utah Seismic Safety Advisory Council, a state agency established by legislative act to recommend and guide Utah's earthquake programs. He has served on the Board of Directors of the Earthquake Engineering Research Institute and chaired the Public Policy and Publications Committees of that organization. Additionally, he has served on research review committees for the National Academy of Sciences, the National Science Foundation, and the Federal Emergency Management Agency, either directly or through contractors to those agencies.

Since 1985, he has served on the examination-writing committee of the National Council of Architectural Registration Boards, the professional organization through which architectural licensing examinations are prepared. His involvement with that group has been in the divisions of general structures and lateral forces.

Published reports, papers, lectures, and technical studies by Mr. Ward number in excess of 150. These writings appear in various books, journals, proceedings, and separate booklets. All of the published work deals with building technology.

Most recently, Mr. Ward is co-author of a book on seismic design principles for architects titled Seismic and Wind Loads in Architectural Design: An Architect's Study Guide. A second edition of the work will be released by the American Institute of Architects in June of 1990. This book is a principal reference for architects preparing for licensing examinations.

James E. Beavers, Ph.D., P.E.

Dr. Beavers currently serves on the Board of Directors of the Earthquake Engineering Research Institute and is editor of the Institute's professional journal Earthquake SPECTRA. He served as chairman of EERI's "Third U.S. National Conference on Earthquake Engineering" held in Charleston, SC (1986) and has been a member of the Strong Motion, Public Policy and Nominating committees. He was also a principal organizer of the first major earthquake conference to focus on earthquake hazards and risks in the eastern U.S. held in Knoxville, Tennessee (1981) and was editor of the two volume proceedings "Earthquakes and Earthquake Engineering: The Eastern United States." He is a member of the National Academy of Sciences and Engineering's National Research Council Committee on Earthquake Engineering and was chairman of its Advisory Panel for a National Earthquake Engineering Experimental Facility. He is a member of the Scientific Advisory Committee for the National Center for Earthquake Engineering Research, has served as a member of the National Science Foundation's Advisory Panel for Critical Engineering Systems and a chairman of the Seismic Advisory Panel for the Governor of Tennessee.

Dr. Beavers has been chairman or a member of numerous other national, state and local professional committees; has authored or coauthored over fifty papers, articles and reports; has been guest lecturer/invited speaker at over fifty university and civic functions; has lectured for the International Atomic Energy Agency's Nuclear Power Program at Argonne National Laboratory; and has taught at the University of Tennessee. His professional honors include National Outstanding Young Engineer by the National Society of Professional Engineers (1977), Rotary Foundation exchange program participant with the peoples of India (1980), Honor Member of the National Civil Engineering Rolla (1987), Outstanding Technical Achievement Award - Martin Marietta Energy Systems, Inc. (1987), Engineer of the Year - State of Tennessee (1987), National Award of Merit - American Society for Engineering Management (1989), and appointment as a Martin Marietta Fellow (1990).

He received his B.S. degree in Civil Engineering from the University of Missouri at Rolla and his M.S. and Ph.D. degrees in Structural Engineering from Vanderbilt University. He is a registered Professional Engineer in Tennessee and Mississippi and is a member of several technical and professional societies, including the American Society of Civil Engineers (Fellow), the Seismological Society of America and the National Society of Professional Engineers. He has served as President of the Knoxville Branch, Tennessee Valley Section and Tennessee Section of ASCE; President of the Oak Ridge Chapter, Tennessee Society of Professional Engineers and Vice President of the Tennessee Society of Professional Engineers.

He is on the Senior Staff of the Engineering Divisions at Martin Marietta Energy Systems, Inc. which operates the Department of Energy's Oak Ridge National Laboratory, (Oak Ridge, TN), Uranium Enrichment Plants (Oak Ridge, TN; Paducah, KY; and Portsmouth, OH) and Y-12 Plant (Oak Ridge, TN) with over 18,000 employees.

George K. Bernstein

An attorney in Washington, D.C., and New York City, Mr. Bernstein advises and represents insurers, agents, brokers and State Insurance Departments on regulatory matters including the chartering and licensing of insurance companies, examinations, compliance with state law, ratemaking, as well as the rehabilitation and liquidation of financially troubled and insolvent insurers. He is also involved in the formation of offshore insurers and of risk retention groups.

Mr. Bernstein also represents insurers and insurance organizations in litigation and before Congress and state legislatures in such areas as financial deregulation, taxation, investment income, rating classifications, workers' compensation, occupational disease including asbestosis and agent orange, medical malpractice, automobile no-fault, and competitive rating. He is frequently called on to testify as an expert witness before legislative committees and in insurance litigation. He is also involved in public housing and real estate matters.

In 1974, Mr. Bernstein received the U.S. Department of Housing and Urban Development's "Distinguished Service Award".

Previously, from 1969 to 1974, Mr. Bernstein served as the first Federal Insurance Administrator. In March of 1972, he was also appointed Administrator of the federal Office of Interstate Land Sales Registration (OILSR). He served in both positions in the U.S. Department of Housing and Urban Development until November 1974, when he resigned to return to the private practice of law. As head of the Federal Insurance

Administration, Mr. Bernstein administered the National Flood Insurance Program, the Federal FAIR (Fair Access to Insurance Requirements) Plan and Riot Reinsurance Program, and the Federal Crime Insurance Program. He also acted as insurance advisor to the White House, and frequently testified before various Congressional committees on behalf of the White House and HUD and as an expert witness. As Interstate Land Sales Administrator, Mr. Bernstein implemented the 1968 federal law requiring full disclosure and registration of unimproved property sold in interstate commerce.

Before coming to Washington in 1969, Mr. Bernstein served with the New York State Insurance Department, first as Deputy Superintendent and General Counsel (beginning in 1964), and from 1967 as First Deputy Superintendent. Before his appointment to the Insurance Department in 1964, Mr. Bernstein practiced law, primarily in the field of insurance, in New York City.

Earlier, from 1957 to 1961, as Assistant Attorney General of the State of New York in the Litigation and Appeals Bureau, he argued more than 50 appeals in the State and Federal Courts, many of which resulted in landmark decisions in the area of federal-state relations and criminal constitutional law. Among the state agencies that he represented during this period was the New York Insurance Department, and many of the matters he handled had precedent-setting impact on the insurance business and its regulation.

Mr. Bernstein received his B.A. from Cornell University in 1955 and his LL.B. from Cornell Law School in 1957. At law school, he has the winner of the Moot Court Competition and was Chairman of the Moot Court Board.

He was admitted to the New York Bar in 1957, the United States Court of Appeals, Second Circuit, in 1958, the United States Supreme Court in 1972, and the District of Columbia Bar in 1973.

Mr. Bernstein has also served as a United States Delegate to the NATO Conference on Flood Insurance, 1970; United States Government Consultant to the Japanese Government on Flood and National Disaster Insurance, 1972; Special Counsel to the New York Select Committee on Insurance, 1974-1976; Consultant to the Overseas Private Investment Corporation, 1975-1977 and 1983-1984; Consultant to the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research, 1979-1981.

He was a member of the President's Interdepartmental Committee on Medical Malpractice, 1971-1973; the National Academy of Sciences' Committee on Medical Malpractice, 1972-1973; the Advisory Committee to the New York State Legislature on Recodification of the Insurance Law, 1972-1974; the President's Interdepartmental Study on Workers' Compensation, 1973-1974; and the National Insurance Development Program Advisory Board, 1976-1977.

He recently served as Chairman of the Expert Review Committee for the National Earthquake Hazards Reduction Program. Since 1983, he has been court-appointed Agent for the Vermont Insurance Commissioner as Receiver of the insolvent Ambassador Insurance Company.

He is a member of the Association of the Bar of the City of New York, and is a member of its Committee on Insurance, of which he was Chairman from 1975 to 1978, where he chairs the Subcommittee on Insurer Solvency; the District of Columbia Bar Association; the Federal Bar Association; and the American Bar Assocation, where he serves on the Tort and Insurance Practice Section and the Section on International Law.

George G. Mader, AICP

George Mader received a B.A. with a major in geography in 1952 from UCLA and a Master of City Planning degree from U.C. Berkeley in 1956. He spent 1958-59 as a Fulbright Scholar at the Technological University of Delft in the Netherlands studying city planning in Western Europe. From 1955 to 1958 Mr. Mader was an associate planner on the special staff that prepared the San Mateo County General Plan. From 1959 to 1962 he was senior planner in charge of the current planning division for the San Mateo County Planning Commission.

In 1962 Mr. Mader joined William Spangle and Associates and today is President. As a representative of the firm, he has served as Town Planner for the Town of Portola Valley since 1965 and for the Town of Los Altos Hills from 1968 to 1975. He has prepared background studies for general plans, general plans, and zoning, subdivision and site development regulations. He has performed special studies of slope-density zoning, and has been instrumental in developing new plans and regulations responsive to geologic and seismic hazards. He developed detailed plans for transfer of development credits in sensitive hillside areas of the cities of Claremont and Milpitas.

Mr. Mader has been actively involved in many of the firm's research projects. He was Principal Investigator for a two-year National Science Foundation study of post-earthquake land use planning and recently headed a study of the response to seismic and volcanic warnings in the Long Valley area of California. He consulted for a geotechnical firm establishing approaches for rebuilding the earthquake-damaged city of Ech Cheliff in Algeria and is a member of the project team for the United States-Mexico Earthquake Preparedness Project to improve earthquake safety in the San Diego-Tijuana border area. Under a National Science Foundation grant, he is documenting the Portola Valley experience in use of geologic information in planning.

Mr. Mader has participated in many state, national and international committees and workshops as a spokesman for land use planning to reduce risk from natural hazards. He was a member of the California Seismic Safety Commission from 1975 to 1984 and chairman from 1979 to 1981. He chaired committees for the Commission evaluating State requirements for seismic safety elements and the Special Studies Zones Act. He has served on committees of the President's Office of Science and Technology Policy, the National Research Council, and the National Science Foundation, and also has participated in review groups convened by the United States Geological Survey. He is currently a Policy Advisory Board member for the Bay Area Regional Earthquake Preparedness Project.

Mr. Mader taught city and regional planning courses for U.C. Extension, Berkeley from 1960 to 1964 and was a lecturer in the U.C. Department of City and Regional Planning from 1967 to 1970. He is a senior lecturer in the School of Earth Sciences at Stanford University where, since 1970, he has taught courses in the application of the earth sciences in city and regional planning.

Mr. Mader is a member of the American Planning Association and the American Institute of Certified Planners. Before the consolidation of the American Institute of Planners and American Society of Planning Officials, he was a member of both organizations and held offices in the Northern California Section and the California Chapter of AIP.

Frank E. McClure

Frank McClure is a California registered Structural Engineer, Civil Engineer, and Architect. He graduated from Lowell High School in San Francisco in 1941. He received a B.S. in civil engineering with a major in structural engineering in 1944 from the University of California, Berkeley.

He is an Honorary Member of the national earthquake engineering society, the Earthquake Engineering Research Institute. He served as its president from 1986 through 1988. He is also a member of the American Society of Civil Engineers, Structural Engineers' Association of Northern California, Seismological Society of America, and the International Conference of Building Officials.

Mr. McClure is a Senior Structural Engineer Consultant for earthquake engineering at the Lawrence Berkeley Laboratory, University of California, Berkeley. After serving in the United States Navy, Civil Engineer Corps, as Lt. (j.g.) with the Seabees on Okinawa, he returned to San Francisco where he worked for several consulting structural engineering offices, and public agencies. In 1955, he opened his own consulting structural engineering office in Oakland, which later grew into the firm of Frank E. McClure and David L. Messinger, Consulting Structural Engineers. McClure and Messinger provided professional services in all aspects of structural engineering design of public, industrial and commercial buildings, and specializing in earthquake engineering. He took a position as University Engineer, University of California Systemwide Adminstration in 1976 until he joined the Lawrence Berkeley Laboratory in 1978.

His professional expertise is in the field of earthquake engineering, with specialization in earthquake vulnerability assessment, seismic reconstruction, and earthquake loss estimation. He made field investigations and prepared reports on earthquake damage caused by the 1952 Kern County, 1954 Eureka, 1966 Parkfield, 1969 Santa Rosa, 1971 San Fernando, 1975 Oroville, 1978 Santa Barbara, 1980 Livermore, 1987 Whittier and 1989 Loma Prieta California earthquakes, and the 1964 Alaska, 1967 Caracas, Venezuela, and 1985 Mexico City earthquakes.

He has served as earthquake damage evaluation consultant to the insurance industry and federal agencies. He performed early earthquake loss simulation studies to test the application of earthquake insurance with various deductibles to mitigate earthquake losses.

He has served as a member of the Scientific Advisory Committee, National Center for Earthquake Engineering Research, State University of New York at Buffalo; the National Research Council, Committee on Earthquake Engineering; Department of Energy, Natural Phenomena Hazards Panel; Seismology Code

Development Committee, International Conference of Building Officials; and the State of California, Field Act Advisory Board to the Office of the State Architect; and Advisory Panels for the Building Seismic Safety Council.

Earl Schwartz

Mr. Schwartz began his career with the City of Los Angeles as a Civil Engineering Assistant with the Department of Building and Safety in 1956. During his 33 years of service, he progressed through the ranks by competitive examination. He was appointed Chief of the Department's Earthquake Safety Division in 1977, Chief of the Conservation Bureau in 1982, Chief of the Resource Management Bureau in 1984 and Chief of the Mechanical Bureau in 1988. He was promoted in May of 1989 to his present position of Executive Officer.

Mr. Schwartz attended the City College of New York where he received a B.S. Degree in Civil Engineering, graduating in 1956. He moved to California shortly after graduation. Earl is licensed by the State of California as a civil engineer, structural engineer and a fire protection engineer.

He is a member of numerous professional associations. Presently, he serves as a Director on the Structural Engineers Association State Board. He is a member of the Structural Engineer's Association of Southern California where he is currently Vice-President. He is a member of the State of California Historical Building Code Board and the Earthquake Engineering Research Institute.

Earl has been involved with the Los Angeles City Earthquake Hazard Reduction Program for many years and was responsible for development of the Department's Earthquake Safety Division, serving as its first Chief. The Earthquake Safety Division is responsible for strengthening earthquake hazardous buildings.

Dr. Lidia Lippi Selkregg

Professor Emeritus in the School of Public Affairs at the University of Alaska, Anchorage, Dr. Selkregg received her Doctor of Natural Sciences degree at the University of Florence, Italy, in 1943. She is a Certified Professional Geologist, AIPG 2060 and a State of Alaska licensed professional geologist.

From 1971 to 1986 she was a Professor of Resource Economics and Planning and Senior Scientist, Arctic Environmental Information & Data Center at the University of Alaska. From 1968 to 1971 she served as Planning Consultant/Planning Officer on the Federal Field Committee for Development Planning in Alaska. From 1961 to 1968 she served as Technical Director of Planning/Staff Geologist for the Alaska State Housing Authority. From 1958 to 1961 she was Geologist/Geologist/Engineer for U.S. Army Corps of Engineers in Alaska. From 1951 to 1958 she was Geologist for the Illinois State Geologic Survey. From 1942 to 1951 she was a Consultant Geologist, Professor of Natural Sciences and Assistant Professor at the University of Florence, Italy.

Dr. Selkregg has extensive experience related to the 1964 Alaska earthquake. She (a) organized, coordinated, and monitored the activities of the Engineering-Geology Evaluation Group that she established on March 29, 1964, to prepare geologic reports on the effects of the earthquake, including mapping areas of failure, subsidence, and inundation as they affected Anchorage, Cordova, Seldovia, Seward, and Kodiak; (b) organized, coordinated, and monitored the preparation and implementation of geologic studies related to disaster assessment and post-disaster planning for Anchorage, Valdez, Seldovia, Cordova, and Kodiak; c) developed methods for coordination among local, state, and federal agencies and the Office of the Governor for implementation of redevelopment plans; d) served as geologist, planner, and member of the Anchorage Planning & Zoning Commission, assembly, and State Coastal Zone Management Council advising several planning and engineering consultants who have conducted studies on geotechnical hazards including the National Academy of Science, the Municipality of Anchorage, and the State of Alaska; and e) served as a member of the Anchorage Municipal Assembly, instrumental in establishing a geotechnical commission for the city.

She has published extensively in the fields of groundwater geology, planning, and applied sciences. She was principal author of:

The Day the Earth Shook -- Shock and Aftershock. Alaska Academy of Engineering and Science. Report No. 3, Anchorage, Ak. (1984).

Seismic Hazard Mitigation: Planning and Policy Implementation -- The Alaska Case. National Science Foundation CEEB112632 (1984).

Planning for Earthquake-Prone Regions, Proceedings of PRC-USA Disaster Mitigation Through Architecture, Urban Planning and Engineering, Beijing, China, November 2-6, 1981.

Urban Planning in the Reconstruction in Human Ecology Volume, the Great Alaska Earthquake of 1964. National Academy of Science. (1970)

Effect of Good Friday Earthquake on Anchorage, Alaska, and Urban Reconstruction. American Association of the Advancement of Sciences, Alaska Section. (1964)

William Sommers

William Sommers has spent thirty-five years in local government administration both in the United States and abroad. He is currently the Commissioner of Public Works for Cambridge, Massachusetts.

Prior to that assignment he was the Commissioner of Inspectional Services for the City of Boston from 1985 to 1987. Mr. Sommers served as municipal manager in Bensalem, Pennsylvania; Franklin Township, New Jersey; and from 1982 to 1985 as city manager of Englewood, New Jersey, in the New York Metropolitan area. From 1962 to 1982 he was a foreign service development officer with the U.S. Department of State's Agency for International Development (AID) in Thailand, Vietnam, the Phillipines and Egypt, emphasizing local government and development.

Mr. Sommers holds a B.A. in political science from Middlebury College in Vermont and a master's in public administration from Harvard's Littauer Center for Public Administration. He also attended the Fletcher School of Law and Diplomacy at Tufts University.

Mr. Sommers has authored some 25 articles on local government and recently served on the Technical Advisory Committee for the "Rapid Visual Screening of Buildings for Potential Seismic Hazards."

D. Whiteman

APPENDIX B

ESTIMATION BASES FOR RISK ANALYSES OF TECHNICALLY FEASIBLE LOSS-REDUCTION ACTIVITIES

In order to make socioeconomic evaluations of loss-reduction measures within an earthquake insurance context, one must provide data that at the very least can be used to suggest the costs and benefits of these mitigations. This Appendix presents the results of analyses performed to estimate

(1) risk levels (degree of loss) associated with various levels of seismic (earthquake) frequency and intensity,

(2) dollar values for both implementation costs and conditional loss-reduction benefits of analyzed building practices, and

(3) dollar values for both implementation costs and conditional loss-reduction benefits of analyzed landuse measures.

In other contexts, assurance from experts may be convincing for the evaluation of loss-reduction activities. However, for this project, a more thorough approach was needed, and risk analysis is a commonplace insurance practice. Even uncertain risks are provided special treatment in a framework that emphasizes quantitative estimates. Moreover, outside the insurance context, failure to provide meaningful estimates for risk analyses of specific loss-reduction activities suggests that the proposed measures have not received thorough consideration -- that, for instance, dramatic instances have been highlighted without thorough investigation of the phenomenon.

Eguchi et al. (1989) emphasized the varieties of risk analyses possible and the uneven quality of the models used. Current models of the probability of liquefaction-induced ground failure are divergent enough to lead to widely discrepant estimates. Data on building losses that are either caused by or associated with liquefaction have not been systematically gathered. For some risk analyses, divergences of models used may make little or no difference to the results; for others, these divergences may have far-reaching practical implications.

The use of risk analysis to evaluate promising loss-reduction activities results in, for those mitigations for which current probabilistic models are weak, estimates of risk and risk-reduction that are somewhat suspect. These loss-reduction activities lie especially in the landuse area. For these, we suggest more focused research to develop more suitable models so that meaningful risk estimates can be made. For purposes of this project, we use expert judgment to compensate for current modeling limitations. With respect to building measures, controversies exist over adequacy of models, and divergencies in models developed could lead to very different results. Since this project does not include the considerable funding needed for evaluating the sensitivities of risk estimates to diverse models, the estimation bases used here are policy-level only. As the risk analysis report suggests, there are many possible ways to improve current models, and any risk analysis developed at this stage must be provisional.

B.1 Expected Annual Loss Basis for Calculation

The basic method used in Appendices B and C and illustrated in Appendix D is an expected annual loss method. Benefits of a specific loss-reduction activity are treated as reduced expected losses. Reduced expected losses are evaluated in terms of the present value of expected reduced losses over the lifetime of the structure.

The method used for assessing expected annual losses, in its discrete form, is based on the following equation

$$EAL = \sum_{I = I_t}^{I = I_{max}} L_I N_I \qquad \text{(B-1)}$$

Such that

- L_I is the loss for a given type of structure at intensity I
- N_I is the annual frequency of occurrence of intensity I
- I_t is the threshold intensity for damage (here, $I_t = 6.0$)
- I_{max} is the maximum intensity possible (here, $I_{max} = 10.0$)
- I is earthquake intensity (measured in such terms as peak horizontal ground acceleration, peak horizontal ground velocity or Modified Mercalli intensity)

For calculation of direct property benefits, one calculates for a given LRM average annual reduced losses achieved through implementing the specified LRM. Next, one uses a real discount factor such as 3 percent and assumes a given time period such as 80 years for the loss-reduction. Using a standardized discount formula, one can thus estimate the present value of the benefits and compare these with the costs of the loss-reduction measure.

Since we considered many cases in this project, these methods were developed at the University of Pennsylvania into a computer program that also included the analysis of benefits and stakeholder considerations indicated in Appendix C. One of many illustrations is provided in Appendix D. For reconstruction of specific calculations, the reader may select a specific LRM, select a given seismic zone intensity level (Table B-1) and use Table B-5, an assumed facility life-span and an assumed real discount rate, in order to estimate direct property benefits to be compared against costs in Table B-5.

B.2 Sample Intensity Frequency Estimates for Policy-Level Risk Analysis

In the absence of elaborate computer modeling for this project, we developed a simple computerized scheme for modeling various sets of estimates of the frequency of Modified Mercalli Intensity. As indicated in Eguchi et al. (1989), elaborate modeling would require consideration of alternative source zone models, attenuation functions, relative site response factors, and intensity conversion equations as well as the correlation of ground motion estimates for special sites with UBC designated seismic zones (which are determined without respect to relative site response factors).

The simple model used here assumes that the frequency, N_I, of a given Modified Mercalli shaking intensity can be determined in terms of the following equation:

$$N_I = \exp(bI + a) \qquad \text{(B-2)}$$

in which b = the slope coefficient, which directly represents the ratio of frequencies of lower to higher intensities

a = the volume coefficient, which relative to a specific b-value represents the relative frequency of specific intensities

I = Modified Mercalli Intensity (defined in terms of strong ground motion criteria).

This model provides an adequate basis for policy-level risk analysis.

The seismic hazard zones of interest in this risk and decision analysis are 2 (or 2*), 3, and 4. As a first crude approximation, one may assume that the (bedrock) intensities for each of these zones with a 10% chance of non-exceedance in 50 years (or roughly a 475 year return interval) are VII, VIII, and perhaps IX, respectively. These very roughly correlate with peak horizontal accelerations of 0.1g, 0.2g, and 0.4g. However, there may be a wide variation in the actual intensities expected at different sites within these zones as functions of proximity to active faults, local geologic effects, and a variety of other local wave propagation effects. Moreover, based on previous studies, we have allowed the b-value to range from -1.1 to -1.5, the latter being a more typical value for worldwide seismicity and the former suggesting proximity to a fault system with high magnitude potential. (The rule of thumb on p. 30 of Algermissen and Perkins, 1976, roughly corresponds to a b-value of -1.5.)

Based on these considerations and tested in terms of previous intensity estimates, (especially Taylor, Atkisson and Petak, 1981), we have developed Table B-1 to derive a range of possible intensity frequency estimates for the various zones of interest. As compared to Taylor, Atkisson, and Petak (1981), the values proposed here are conservative. As compared to estimates in BSD (1989, p. 22), Supporting Document, the estimates provided here are also conservative. For seismic zone 4, our estimates are more conservative except at intensity X. BSD estimates tend to be low-to-intermediate relative to our seismic zone 3 estimates. For seismic zone 2, BSD estimates tend to be intermediate except that they are lower for intensities VI and VII. The range of values proposed in Table B-1, however, allows for sensitivity analyses of possible outcomes.

TABLE B-1
SUMMARY TABLE FOR DIVERSE INTENSITY ESTIMATES

Seismic Zone(s)	I_{500}	b
2	7.0	-1.5
2* or 3	7.5	-1.2
2* or 3	7.5	-1.5
2* or 3	8.0	-1.5
2* or 3	8.0	-1.2
3	8.5	-1.2
3	8.5	-1.5
3 or 4	9.0	-1.1
3 or 4	9.0	-1.5
4	9.5	-1.1
4	10.0	-1.1
4	9.5	-1.5

Note: I_{500} is the shaking intensity expected every 500 years. b is the value provided in equation (B-1) in order to derive "a" and hence other intensity estimates.

B.3 Estimates of Costs and Conditional Benefits for Analyzing Building Practice LRMs

Given estimates of intensity frequencies for the different macrozones, to evaluate building practice LRMs it is necessary to

- o formulate them in a risk and decision framework,
- o estimate costs, and
- o estimate benefits conditional on the occurrence of specific intensities.

The formulation of loss-reduction activities has been made in terms of contrasts between structural types given the status quo and the mitigated structure relative to building practice LRMs specified and numbered in Table 3-2. For instance, activities numbered 100 through 160 involve implementation of seismic code designs. To illustrate these mitigations, we have selected five representative types of structures for which the loss-reduction activity might be applicable. For sensitivity analysis purposes, we also include the more generic categories from Wiggins and Taylor (1986), which suggest that less seismically resistant buildings tend to perform more poorly than is indicated by some building loss algorithms. In each case, we contrast the status quo (unmitigated) with the mitigated situation. Types of structures have been selected because they either are potentially hazardous structures or they are residential sector structures. Subcases considered also incorporate possible differences in costs for seismic design and retrofit in diverse seismic zones.

Tables B-2, B-3, and B-4 are used to develop and document Table B-5, which contains

- o a full listing of representative subcases for each loss-reduction activity,
- o average cost estimates for implementation, and
- o estimated benefits at different intensities.

Table B-2 contains estimated seismic retrofit costs for various cases. Table B-3 contains estimated conditional benefits for various subcases with respect to seismic design. Table B-3 contains both status quo and mitigated new design estimates of losses expected at different intensities. Table B-4 contains both status quo and mitigated (retrofit) estimates of losses expected at different intensities. Table B-5 thus draws on these tables to develop cost and conditional estimates for proposed building measures, including subcases relating to building types and seismic zones. All estimates in Tables B-2 through B-5 are documented in footnotes (at the end of this appendix).

TABLE B-2

ESTIMATED RETROFIT COSTS FOR VARIOUS BUILDING PRACTICE LOSS-REDUCTION ACTIVITIES

Structural Systems		Seismic Zone	Average Replacement Cost	Direct Retrofit Costs			Retrofit Cost % of Replacement
Original System	Retrofit System		$/ft2	Sources/ Notes	$/ft2 Range	$/ft2 Use	(Cost)
Unreinforced Masonry (URM) (Includes Infill Walls)	Partially Reinforced Masonry	2*	50	1,2	5 - 40	20	40
		3	60		5 - 50	20	33
		4	65		4 - 72	15	23
Non-Ductile Concrete Frames (Cast-In-Place)	1. Semi-Ductile Concrete Frames, or	2*	65	3,4	10 - 40	15	23
		3	70		10 - 45	15	21
		4	75		10 - 50	15	20
	2. Concrete Shear Walls						
Concrete Tilt-Up Shear Walls (Pre-1976)	Improved Concrete Tilt-Up Shear Walls (Post-1976)	2*	30	5,6,7	1 - 25	3	10
		3	30				10
		4	35				8
Pre-Cast Concrete Frames -- Non-Ductile	1. Semi-Ductile Concrete Frames, or	2*	60	8,9	10 - 40	15	25
		3	60		10 - 45	20	33
		4	65		10 - 50	20	30
	2. Concrete Shear Walls						
Unbraced Parapets/ Ornamentation (URM, RM, Concrete, etc)	Braced/Removed Parapets	2*,3,4	50	10,11	0.50-1.50	1	2
Dwellings (Wood Frame + Others)		2*,3,4	50	12			
Unanchored to Foundation	Anchored				1.00-1.50	1.00	2
Cripple Wall	Wall Reinforced at Foundation				0.50-1.00	1.00	2
Unreinforced Chimney	Chimney Reinforced, Removed or Replaced				2.00-3.00		6
					3.00-5.00	3.00	
Story Over Garage-Unreinforced	Story Over Garage-Reinforced				15 - 25	20.00	40
Mobile Homes (Unbraced)	Mobile Homes (Braced)	2*,3,4	30	12	0.50-1.50	1.00	3

TABLE B-3

CONDITIONAL SEISMIC BENEFITS FOR NEW DESIGN BY SEISMIC ZONE

Structural Systems: Without Seismic Design	Structural Systems: With Seismic Design	Seismic Zone	MMI	Damage = Loss: No New Design: Damage Factor%	Damage = Loss: No New Design: Assumption	Damage = Loss: New Design: Damage Factor%	Damage = Loss: New Design: Assumption	Loss Reduction (% Repl. Cost)
Unreinforced Masonry	Reinforced Masonry	3	6	4.0	(2)	1.0	(3)	3.0
			7	11.0		3.0		8.0
			8	34.0		8.0		26.0
			9	56.0		16.0		40.0
			10	77.0		27.0		50.0
		2*	6	4.0	(2)	2.0	(4)	2.0
			7	11.0		5.5		5.0
			8	34.0		12.0		22.0
			9	56.0		23.0		33.0
			10	77.0		37.0		40.0
Non-Ductile Cast-In-Place Concrete Frame	Ductile Concrete Concrete	3	6	1.6	(5)	1.0	(6)	0.6
			7	5.0		2.8		2.2
			8	13.0		5.6		7.4
			9	15.0		11.2		13.8
			10	40.0		18.6		21.4
		2*	6	2.3	(7)	2.1	(6)	0.2
			7	7.5		5.0		2.5
			8	17.0		10.0		7.0
			9	32.0		16.0		16.0
			10	46.0		24.0		22.0
Concrete Tilt-Up Buildings w/o Seismic	Concrete Tilt-Up Buildings w/Seismic	3	6	4.2	(8)	1.0	(9)	3.2
			7	9.6		2.0		7.6
			8	18.2		7.3		10.9
			9	31.6		13.8		17.8
			10	49.2		22.0		27.2
		2*	6	5.0	(10)	1.5	(11)	3.5
			7	11.6		4.0		7.6
			8	22.0		10.6		11.4
			9	38.0		18.5		20.0
			10	60.0		28.7		30.0
Non-Ductile Precast Concrete Frames	Ductile Concrete Frame	3	6	3.0	(12)	1.0	(6)	2.0
			7	6.5		2.5		4.0
			8	15.3		5.6		10.0
			9	32.0		11.2		21.0
			10	52.0		18.6		33.0

TABLE B-3
(Continuation)

Structural Systems: Without Seismic Design	Structural Systems: With Seismic Design	Seismic Zone	MMI	Damage = Loss[1]: No New Design: Damage Factor%	No New Design: Assumption	New Design: Damage Factor%	New Design: Assumption	Loss Reduction (% Repl. Cost)
		2*	6	4.5	(13)	2.0	(6)	2.5
			7	9.5		5.0		4.5
			8	22.0		10.0		12.0
			9	40.0		16.0		24.0
			10	62.0		24.0		38.0
Wood Dwellings	Wood Dwellings	2*,3	6	2.6	(14)	0.8	(14)	2.0
Unachored and/or	Anchored and		7	4.8		1.5		3.5
Unreinforced	Reinforced		8	11.0		4.7		6.5
			9	19.7		9.2		11.0
			10	39.8		19.8		22.0
Mobile Homes-	Mobile Homes-	2*,3	6	4.7	(15)	0.8	(15)	4.0
Unanchored and/	Anchored and		7	11.0		3.0		8.0
or Unreinforced	Reinforced		8	17.4		6.0		12.0
			9	30.0		16.0		15.0
			10	48.0		28.0		20.0
Q = 1	Q = 2	2	6	0.13	(16)	0.06	(16)	0.07
(Commercial)	(Commercial)		7	4.5		0.9		3.6
			8	79.4		6.9		72.5
			9	100.0		28.2		71.8
			10	100.0		100.0		0.0
Q = 1	Q = 2	2	6	0.46	(16)	0.28	(16)	0.18
(Residential)	(Residential)		7	14.5		6.5		8.0
			8	29.6		13.3		16.3
			9	63.2		27.4		35.8
			10	100.0		56.2		43.8
Q = 1	Q = 3	3	6	0.13	(16)	0.06	(16)	0.07
(Commercial)	(Commercial)		7	4.5		0.6		3.9
			8	79.4		3.1		76.3
			9	100.0		6.7		93.3
			10	100.0		14.5		85.5
Q = 1	Q = 3	3	6	0.46	(16)	0.20	(16)	0.26
(Residential)	(Residential)		7	14.5		3.0		11.5
			8	29.6		5.9		23.7
			9	63.2		11.7		51.5
			10	100.0		23.4		76.6

TABLE B-4

CONDITIONAL SEISMIC BENEFITS FOR RETROFIT BY SEISMIC ZONE

Structural Systems		Seismic Zone	MMI	Damage = Loss[1]				Loss Reduction (% Repl. Cost)
				As Is		Retrofit		
Original	Retrofit			Damage Factor%	Assumption/ Source	Damage Factor%	Assumption/ Source	
Unreinforced Masonry (URM)	Partially Reinforced Masonry	2*,3,4	6	4.0	(2)	2.8	(3)	1.2
			7	12.0		8.0		4.0
			8	34.0		17.0		17.0
			9	56.0		30.0		25.0
			10	77.0		46.0		30.0
Non-Ductile Cast-in-Place Concrete Frames	a) Semi-Ductile Concrete Frames or b) Concrete Shear Walls	3,4	6	1.6	(4)	1.0	(5)	0.6
			7	5.0		3.4		1.6
			8	13.0		7.0		6.0
			9	25.0		14.0		11.0
			10	40.0		24.0		16.0
		2*	6	2.3	(6)	1.9	(5)	0.4
			7	7.5		5.4		2.1
			8	17.0		11.0		6.0
			9	32.0		20.0		12.0
			10	46.0		30.0		16.0
Concrete Tilt-Up Wall Buildings (Pre '76 UBC)	Improved Concrete Tilt-Up Wall Buildings	3,4	6	4.2	(7)	1.0	(8)	3.2
			7	9.6		2.0		7.6
			8	18.2		7.3		10.9
			9	31.6		13.8		17.8
			10	49.0		22.0		27.0
		2*	6	5.0	(9)	1.5	(10)	3.5
			7	11.6		4.0		7.6
			8	22.0		10.6		11.4
			9	38.0		18.5		20.0
			10	60.0		28.7		30.0
Non-Ductile Pre-Cast Concrete Frames	a) Semi-Ductile Concrete Frames or b) Concrete Shear Walls	3,4	6	3.0	(11)	1.0	(5)	2.0
			7	6.5		3.4		3.0
			8	15.3		7.0		8.0
			9	32.0		14.0		18.0
			10	52.0		24.0		28.0
		2*	6	4.5	(12)	1.9	(5)	2.5
			7	9.5		5.4		4.0
			8	22.0		11.0		11.0
			9	36.0		20.0		16.0
			10	62.0		30.0		32.0

TABLE B-4
(Continuation)

Structural Systems		Seismic Zone	MMI	Damage = Loss[1]				Loss Reduction (% Repl. Cost)
				As Is		Retrofit		
Original	Retrofit			Damage Factor%	Assumption/ Source	Damage Factor%	Assumption/ Source	
Wood Dwellings -Unanchored and Unreinforced	Wood Dwellings Anchored and Reinforced	2*,3,4	6	2.6	(13)	0.8	(13)	1.8
			7	4.8		1.5		3.3
			8	11.0		4.7		6.3
			9	19.7		9.2		10.5
			10	39.8		19.8		20.0
Mobile Homes - Unanchored and Unreinforced	Mobile Homes - Anchored and Reinforced	2*,3,4	6	4.7	(14)	0.8	(14)	4.0
			7	11.0		3.0		8.0
			8	17.4		6.0		11.5
			9	30.0		16.0		14.0
			10	48.0		28.0		20.0
Q = 1 (Commercial)	Q = 2 (Commercial)	3,4	6	0.13	(15)	0.06	(15)	0.07
			7	4.5		0.9		3.6
			8	79.4		6.9		72.5
			9	100.0		28.2		71.8
			10	100.0		100.0		0.0
Q = 1 (Commercial)	Q = 3 (Commercial)	4	6	0.13	(15)	0.06	(15)	0.07
			7	4.5		0.6		3.9
			8	79.4		3.1		76.3
			9	100.0		4.7		93.3
			10	100.0		14.5		85.5
Q = 1 (Residential)	Q = 2 (Residential)	3	6	0.46	(15)	0.28	(15)	0.18
			7	14.5		6.5		8.0
			8	29.6		13.3		16.3
			9	63.2		27.4		36.8
			10	100.0		56.2		43.8
Q = 1 (Residential)	Q = 3 (Residential)	3,4	6	0.46	(15)	0.20	(15)	0.26
			7	14.5		3.0		11.5
			8	29.6		5.9		23.7
			9	63.2		11.7		51.5
			10	100.0		23.4		76.6

TABLE B-5

COSTS AND CONDITIONAL BENEFITS FOR BUILDING MEASURES ANALYZED

Table 3.2 #	SEISMIC ZONE	CONDITION BEFORE IMPLEMENTATION	CONDITION AFTER IMPLEMENTATION	AVERAGE COST TO IMPLEMENT (% RC)	SOURCE/ COMMENT	ESTIMATED AVERAGE LOSS REDUCTION (% Replacement Cost) AT MMI VI	VII	VIII	IX	X	SOURCE/ COMMENT
110, 160	3	Q = 1 (Commercial)	Q = 3 (Commercial)	3		0.1	4	76	93	86	Table B-3
		Unreinforced Masonry	Reinforced Masonry	5	(1),	3	8	26	40	50	
		Non-Ductile CIP Conc Frame	Ductile Concrete Frame	3	(2)	0.6	2	7	14	21	
		Non-Ductile Precast Conc Frame	Ductile Concrete Frame	3		2	4	10	21	33	
		Tilt-up - No Seismic	Tilt-up with Seismic	2		3	8	11	18	27	
		Wood Dwellings - Unanchored	Wood Dwellings - Anchored	2		2	3	6	11	22	
		Q = 1 (Residential)	Q = 3 (Residential)	2		0.3	12	24	52	77	
100, 150	2*	Unreinforced Masonry	Partially Reinforced Masonry	3		2	5	22	33	40	Table B-3
		Non-Ductile CIP Conc Frame	Partially Ductile Conc Frame	2		0.2	2.5	7	16	22	
		Non-Ductile Precast Conc Frame	Partially Ductile Conc Frame	3		2.5	4.5	12	24	38	
		Tilt-up - No Seismic	Tilt-up with Seismic	2		3.5	7.5	11	20	30	
		Wood Dwellings - Unanchored	Wood Dwellings - Anchored	1		2	3	6	11	22	
		Q = 1 (Residential)	Q = 2 (Residential)	1		0.2	8	16	36	44	
		Q = 1 (Commercial)	Q = 2 (Commercial)	2		0.1	3.6	73	72	0	
120	2*	Partially Reinforced Masonry	Reinforced Masonry	1	(2),	1.0	2.0	3.0	4.5	6	(4)
		Partially Ductile Conc Frame	Ductile Concrete Frame	1	(3)	0.5	1.5	2.4	3.0	5	
		Tilt-up	Improved Tilt-up	0.5		0.3	1.0	1.7	2.0	5	
180, 190	3, 4	Unreinforced Masonry	Partially Reinforced Masonry	25	Table B-2	1.2	4.0	17	25	30	(5) and Table B-4
		Non-Ductile CIP Concrete Frame	Semi-Ductile Frame/Shear Wall	20		0.6	1.6	6	11	16	
		Non-Ductile Precast Conc Frame	Semi-Ductile Frame/Shear Wall	30		2.0	3.0	8	18	28	
		Tilt-Up (pre'76)	Improved Tilt-Up	9		3.2	7.6	11	18	27	
		Q = 1 (Commercial)	Q = 2 (Commercial)	20		0.1	3.6	73	72	0	
170	2*	Unreinforced Masonry	Partially Reinforced Masonry	40		1.2	4.0	17	25	30	
		Non-Ductile CIP Concrete Frame	Semi-Ductile Frame/Shear Wall	23		0.4	2.1	6	12	16	
		Non-Ductile Precast Conc Frame	Semi-Ductile Frame/Shear Wall	25		2.5	4.0	11	16	30	
		Tilt-Up	Improved Tilt-Up	10		3.2	7.6	11	20	30	
		Q = 1 (Commercial)	Q = 2 (Commercial)	20		0.1	3.6	73	72	0	

TABLE B-5
(Continuation)

Table 3.2 #	SEISMIC ZONE	CONDITION BEFORE IMPLEMENTATION	CONDITION AFTER IMPLEMENTATION	AVERAGE COST TO IMPLE-MENT (% RC)	SOURCE/ COMMENT	ESTIMATED AVERAGE LOSS REDUCTION (% Replacement Cost) AT MMI *					SOURCE/ COMMENT
						VI	VII	VIII	IX	X	
230	4	Unreinforced Parapet Walls	Reinforced/Removed Parapet Walls	2	Table B-2	0.2	0.7	1.7	2.8	3.8	(6)
170	2*	Unreinforced Masonry	Partially Reinforced Masonry	21	(9)	2.0	6	21	31	38	(8)
		Non-Ductile CIP Concrete Frame	Semi-Ductile Conc Frame/ Shear Wall	12		0.6	3	8	15	21	
		Non-Ductile Precast Conc Frame	Semi-Ductile Conc Frame/ Shear Wall	14		3.0	5	13	21	36	
		Tilt-Up	Improved Tilt-Up	6		3.2	8	12	21	33	
		Q = 1 (Commercial)	Q = 2 (Commercial)	20		0.1	4	73	72	0	
130, 140, 200, 210, 220	2,3,4	Wood Dwelling - Unanchored	Wood Dwelling - Anchored	2	(10) and Table B-2	1.5	2.5	5	8	15	(11)
		Q = 1 (Residential)	Q = 3 (Residential)	2		0.3	12	24	52	77	
240	4	Unanchored Water Heaters	Strapped/Anchored Water Heater	0.2	(13)	0.01	0.1	0.5	1	2	(12)
250, 260	3,4	Unanchored Equipment	Anchored Equipment	2.0	(14)						

The approach taken here permits the general loss-reduction activities to be disaggregated into subcases. The socioeconomic analysis thus provided illustrative ratings of these disaggregated subcases and aggregated them again differently based on these ratings. Likewise, public policy and legal analyses yielded more diverse combinations of subcases than those initially proposed from an engineering standpoint.

Many qualifications need to be made of the results here. First, as indicated in Eguchi et al. (1989), there is no single universally accepted scheme for estimating losses at specific intensities. The conditional estimates produced here could be compared to estimates produced by other schemes in order to determine further the sensitivity of results to diverse estimation methods. Second, the procedures used here employ only mean estimates of costs and conditional benefits. As a result, the scatter among possible cases is ignored. The treatment of outliers or cases with special circumstances, such as clear cases in which retrofits can be achieved more economically, may be ignored. In view of these and other considerations (many of which are discussed in the project risk analysis report), the risk analysis results should be regarded as being chiefly for policy-level purposes.

B.4 Illustrative Decision Alternatives to Analyze Landuse LRMs

As mentioned earlier, it is difficult to develop seismic risk estimation models for landuse measures. Data tend to be lacking for assessing the likelihood and severity of given hazards (except perhaps for the occurrence of surface fault rupture in well-defined fault zones of deformation) and for estimating the degree of loss from these hazards. Moreover, unlike building measures, landuse measures often involve real estate considerations other than structural replacement and/or retrofit costs. For these reasons, the alternatives presented here will be merely for current policy-level analyses. Risk and decision analyses of these alternatives may at least suggest conditions under which various landuse measures may be warranted in socioeconomic terms (such as by virtue of community liabilities that may otherwise be incurred should such measures not be adopted).

Table B-6 summarizes representative landuse measures evaluated in seismic risk and decision analyses. These parallel to a large extent those activities identified in Section 3; however, the loss-reduction activities identified in Section 3 have been listed in Table B-6 in order to develop specific risk and decision outputs. In addition, the view in Section 3 that an Alquist-Priolo Act can be extended to potential ground failures other than surface fault rupture has been broken down into the three major sources of ground failures examined here: liquefaction, landslide, and faulting. Results of risk and decision analyses can be combined to consider measures that incorporate all three sources in one measure.

TABLE B-6
REPRESENTATIVE LANDUSE MEASURES
FOR POLICY-LEVEL RISK AND DECISION ANALYSIS

Number	Brief Description
1000	Purchase (if necessary) existing construction or properties in very active fault zones of deformation (hence in seismic zone 4) and convert to low-density purposes or open space only.
1100	Purchase (if necessary) existing construction or properties in moderately active fault zones of deformation and convert to low-density usage or open space only.
1200	Restrict new development in very active fault zones of deformation (in seismic zone 4) to low-rise residential construction. (Assume that residences and other construction would be designed to seismic code.)
1300	Restrict new development in moderately active fault zones of deformation in seismic zone 4 to low-rise residential construction. (Assume that residences and other construction would be designed to code.)
1400	Restrict new development in moderately active fault zones of deformation in seismic zone 3 to low-rise residential construction. (Assume that residences and other construction would be designed to code.)
1500	In seismic zone 4 as deemed appropriate by geotechnical engineers prior to development, drive piles, use vibro-compaction, or use dynamic deep compaction in order to minimize potential ground failures owing to liquefaction. (Assume that seismic codes are adopted and enforced.)
1600	In seismic zone 3, as deemed appropriate by geotechnical engineers prior to development, drive piles, use vibro-compaction, or use dynamic deep compaction in order to minimize ground failures owing to liquefaction. (Assume that seismic codes are adopted and enforced.)
1700	In seismic zone 4 restrict new development in very susceptible liquefaction zones to low-rise residential structures.
1800	In seismic zone 3 restrict new development in very susceptible liquefaction zones to low-rise residential structures.
1900	In seismic zone 4 allow major modifications of existing structures in very susceptible liquefaction zones only for which suitable geotechnical techniques can be used to minimize hazards resulting from ground failures.
2000	In seismic zone 3 allow major modifications of existing structures in very susceptible liquefaction zones only for which suitable geotechnical techniques are used to minimize hazards resulting from ground failures.
2100	In seismic zone 4, in very susceptible landslide locales, restrict new development to open-space uses.
2200	In seismic zone 3, in landslide locales, restrict new development to open-space uses.
2300	In seismic zone 4 purchase (if necessary) land and/or severely damaged construction and convert existing development in very susceptible landslide locales to open-space uses.
2400	In seismic zone 3 purchase (if necessary) land and/or severely damaged construction and convert existing development in very susceptible landslide locales to open-space uses

In Table B-6, loss-reduction activities 1000, 1100, 2300, and 2400 involve purchase of existing properties. For policy-level risk and decision analyses, we assume that the structures purchased have been rebuilt elsewhere -- presumably on locations without severe ground failure potential. We further assume that the strong ground motions expected in the new locations are no worse than those in the fault zone of deformation or landslide zone. In practice, these options may not be available in a few jurisdictions. (E.g., Davis County, Utah, has limited options.) Land for development may be limited to fault zones of deformation, high liquefaction or landslide susceptible zones, or regions with high relative strong motion site response factors. Even where better options are available for seismic hazards, other natural hazards may further constrain available options.

Table B-7 supplemented by Table B-8 is designed to illustrate costs of loss-reduction activities. Even though the benefits of such measures as 1000, 1100, 2300, and 2400 may be high, the costs are often extreme. It is anticipated that there will be only special circumstances under which such loss-reduction activities could be warranted in socioeconomic terms. These circumstances include extreme life-safety risks, extremely high mandated insurance premiums, or buildings that are approaching the end of their life-cycle but whose functions are vital or extremely remunerative.

TABLE B-7
POLICY-LEVEL COST CONSIDERATIONS FOR LANDUSE LRMs ANALYZED

Number	Description of costs (all presuppose mapping, survey, testing, and administrative costs)
1000, 1100	Costs of properties purchased. These may be low or high depending on market considerations. Cost of properties includes land values and for existing construction the market value of structures. Relocation and other costs may be involved. Assume 2x (replacement value of structure) as a rough estimate of these variable costs.
1200, 1300, 1400, 1700, 1800	Loss of market value of properties zones for commercial, industrial, or high-occupancy residential usage.
1500, 1600	Costs of liquefaction mitigation techniques if and as required. Based on Table B-2, Table B-8, and 1988 Building Valuation Data for Los Angeles, we assume that costs are 2-3 percent of replacement costs except for dwellings, for which costs are as much as 10 percent of replacement cost but which could be reduced to perhaps 4 percent if piles were provided for many wood frame dwellings in a tract.
1900, 2000	Costs for existing structures are perhaps double those for LRMs 1500 and 1600.
2100, 2200, 2300, 2400	Cost of land (assume to be a percent of replacement cost)

TABLE B-8
SAMPLE COSTS FOR PROJECTS TO MINIMIZE LIQUEFACTION/SETTLEMENT PROBLEMS IN NEW DEVELOPMENTS

STRUCTURE TYPE	COST NORMAL FOUNDATION[1]	LIQUEFACTION MITIGATION TECHNIQUE: 1. DRIVE PILES		2. VIBRO-COMPACTION		3. DYNAMIC DEEP COMPACTION		AREA SqFt
		TOTAL	COST/SqFt[2]	TOTAL	COST/SqFt	TOTAL	COST/SqFt	
8-story Commercial	$423,200[4]	$423,200	$18.80	$254,250	$11.30	$105,300	$4.68	22,500
3-story Commercial	$180,000[3]	$195,800	$5.44	$381,600	$10.60	$158,040	$4.39	36,000
2-story Apartment		$37,270	$2.66	$180,600	$12.90	$74,760	$5.34	14,000
School		$82,820	$3.66	$194,812	$8.62	$108,480	$4.80	22,600
House		$20,700	$2.35	$120,912	$13.74	$50,072	$5.69	8,800

[1]These are extra foundation costs required to prevent excessive settlements in loose sands (exclusive of seismic concerns).

[2]Cost per square foot is for area of building footprint (not total floor area).

[3]Figure represents cost of excavation and recompaction of upper 10 feet of loose sands, including dewatering. However, any of the 3 techniques for liquefaction mitigation could be selected here for preventing nonseismic settlements.

[4]Figure represents cost of pile foundation.

Loss-reduction activities numbered 1200, 1300, 1400, 1500, 1600, 1700, 1800, 2100, and 2200 pertain to restrictions on new developments. As this report has consistently emphasized, seismic decisions made or omitted in the siting and design phases are often the most critical in terms of cost-effectiveness. What is chiefly lost in loss-reduction activities 1200, 1300, 1400, 1700, and 1800 is the value of land for commercial/industrial/public and high occupancy residential purposes. The value of land is reduced completely to open-space uses in activities 2100 and 2200. These reductions in the value of land can be considerable in some regions of the country. However, further economic and legal analysis is needed to determine whether or not the externalization of natural hazard losses in land values is one factor (whether small or large) in current market values.

Loss-reduction activities numbered 1900 and 2000 deal with major modifications of existing properties. In these cases we shall assume that seismic retrofit is performed. Moreover, for structures with definite and severe potential problems of liquefaction-induced ground failure, we shall assume that geotechnical engineering techniques are used to eliminate or minimize potential ground failure hazards. Table B-8 summarizes costs for various sample projects used prior to development. In dealing with potentially deep subsurface liquefaction potential, and in securing the building against likely liquefaction problems at depth, we assume that piles or vibro-compaction techniques are used, whichever is less expensive. Deep dynamic compaction(DDC) techniques may be used but may be less effective. Even with the use of piles, some further densification may lead to damage of the structure. Comparing these cost estimates with 1988 building cost for the Los Angeles region and with replacement costs per square foot as estimated previously in Table B-5, we speculate that costs for non-dwellings run about 2-3 percent of replacement value. Economies of scale exist for implementing these techniques for residential development. Costs for piles for a single new dwelling may run 10 percent of replacement value; for a tract development, costs may be decreased to perhaps 4 percent of replacement value. These cost estimates need to be further considered in future studies. For illustrative purposes only, we assume that costs for existing structures are twice those for new developments.

Table B-9 outlines in greater detail the loss-reduction activities represented and various policy-level conditional benefits. Table B-9 draws largely from intensity frequency estimates discussed in Section B.2 in terms of loss in order to calculate estimates for strong ground motion hazards alone and for diverse structural classes. As with the estimation of conditional benefits from structural loss-reduction activities, each subcase is developed to represent a category of structure and a status quo situation is contrasted to a mitigated situation in terms of direct structural property benefits.

TABLE B-9

CONDITIONAL BENEFITS (% of replacement cost for structure only) FOR LANDUSE MEASURES (including subcases as defined in the table)

Number	Definition of Subcase (both status quo = S and after mitigation = A in terms of structure type)		Expected Loss at Specified Intensity				
			Intensity				
			VI	VII	VIII	IX	X
1000	In very active fault zones of deformation, purchase properties and replace elsewhere at sites subject only to strong ground motion (seismic zone 4)						
1001	S =	Unreinforced Masonry	4.0	11.0	34.0	100.0	100.0
	A =	Reinforced Masonry	1.0	3.0	8.0	16.0	27.0
1002	S =	Reinforced Masonry	1.0	3.0	8.0	100.0	100.0
	A =	Reinforced Masonry	1.0	3.0	8.0	16.0	27.0
1003	S =	Non-ductile cast-in-place concrete	1.6	5.0	13.0	100.0	100.0
	A =	Make ductile	1.0	2.8	5.6	11.2	18.6
1004	S =	Ductile c-i-p concrete	1.0	2.8	5.6	100.0	100.0
	A =	Ductile c-i-p concrete	1.0	2.8	5.6	11.2	18.6
1005	S =	Non-seismic tilt-up	4.2	9.6	18.2	100.0	100.0
	A =	Seismic tilt-up	1.0	2.0	7.3	13.8	22.0
1006	S =	Seismic tilt-up	1.0	2.0	7.3	100.0	100.0
	A =	Seismic tilt-up	1.0	2.0	7.3	13.8	22.0
1007	S =	Non-ductile pre-cast concrete frame	3.0	6.5	15.3	100.0	100.0
	A =	Ductile pre-cast	1.0	2.5	5.6	11.2	18.6
1008	S =	Ductile pre-cast	1.0	2.5	5.6	100.0	100.0
	A =	Ductile pre-cast	1.0	2.5	5.6	11.2	18.6
1009	S =	Unanchored wood dwelling	2.6	4.8	11.0	100.0	100.0
	A =	Anchored wood dwelling	0.8	3.0	6.0	16.0	28.0
1010	S =	Anchored wood dwelling	0.8	3.0	6.0	100.0	100.0
	A =	Anchored wood dwelling	0.8	3.0	6.0	16.0	28.0
1011	S =	Unanchored mobile home	4.7	11.0	17.4	100.0	100.0
	A =	Anchored mobile home	0.8	3.0	6.0	16.0	28.0
1012	S =	Unanchored mobile home	0.8	3.0	6.0	100.0	100.0
	A =	Anchored mobile home	0.8	3.0	6.0	16.0	28.0

TABLE B-9 (Continued)

Number		Definition of Subcase (both status quo = S and after mitigation = A in terms of structure type)	Expected Loss at Specified Intensity				
			Intensity				
			VI	VII	VIII	IX	X
1100		Purchase properties in moderately active fault zones and replace elsewhere (seismic zone 4).					
	1101-1102	defined as 1001-1012	Benefits defined as 1001-1012 except that status quo (S) cases are defined as follows at Intensity IX:				
			78.0,	58.0,	57.5,	55.6,	65.8,
			56.9,	66.0,	55.6,	59.8,	54.5,
			65.0,	58.0, respectively.			
1200		Restrict new developments in very active fault zones (seismic zone 4). Assume code adoption, compliance, and enforcement.					
	1201	S = Reinforced masonry A = Reinforced masonry	Use 1002				
	1202	S = Ductile c-i-p concrete A = Ductile c-i-p concrete	Use 1202				
	1203	S = Seismic tilt-up A = Seismic tilt-up	Use 1006				
	1204	S = Ductile pre-cast concrete A = Ductile pre-cast concrete	Use 1008				
1300		Restrict new developments in moderately active fault zones (seismic zone 4). Assume code adoption, compliance, and enforcement.					
	1301	S = Reinforced masonry A = Reinforced masonry	Use 1102				
	1302	S = Ductile c-i-p concrete A = Ductile c-i-p concrete	Use 1104				
	1303	S = Seismic tilt-up A = Seismic tilt-up	Use 1106				
	1304	S = Ductile pre-cast concrete A = Ductile pre-cast concrete	Use 1108				

TABLE B-9 (Continued)

Number		Definition of Subcase (both status quo = S and after mitigation = A in terms of structure type)	Expected Loss at Specified Intensity — Intensity VI	VII	VIII	IX	X
1400		Restrict new developments in moderately active fault zones (seismic zone 3). Assume code adoption, compliance, and enforcement.					
	1401	S = Reinforced masonry A = Reinforced masonry	Use 1102				
	1402	S = Ductile c-i-p concrete A = Ductile c-i-p concrete	Use 1104				
	1403	S = Seismic tilt-up A = Seismic tilt-up	Use 1106				
	1404	S = Ductile pre-cast concrete A = Ductile pre-cast concrete	Use 1108				
1500		Use the least costly geotechnical technique to eliminate or minimize liquefaction-induced ground failures and/or differential settlement (seismic zone 4).					
	1501	S = Reinforced Masonry	1.0	13.5	27.0	27.0	27.0
		A = Reinforced Masonry	1.0	3.0	8.0	16.0	27.0
	1502	S = Ductile c-i-p concrete	1.0	9.4	18.6	18.6	18.6
		A = Ductile c-i-p concrete	1.0	2.5	5.6	11.2	18.6
	1503	S = Seismic tilt-up	1.0	11.0	22.0	22.0	22.0
		A = Seismic tilt-up	1.0	2.0	7.3	13.8	22.0
	1504	S = Anchored wood frame	0.8	9.9	19.8	19.8	19.8
		A = Anchored wood frame	0.8	1.5	4.7	9.2	19.8
1600		Use the least cost geotechnical technique to eliminate or minimize liquefaction-induced ground failure and/or differential settlement (seismic zone 3).					
	1601-1604 defined as 1501-1504		Use 1501-1504 for 1601-1604, respectively				
1700		Restrict new developments in high liquefaction susceptible regions to dwellings and to structures that have used the least costly geotechnical techniques to eliminate or minimize liquefaction-induced ground failures (seismic zone 4).					
	1701-1703 defined as 1501-1503		Use 1501-1503 for 1701-1703, respectively				

TABLE B-9 (Continued)

Number	Definition of Subcase (both status quo = S and after mitigation = A in terms of structure type)	Expected Loss at Specified Intensity: Intensity VI	VII	VIII	IX	X
1800	Restrict new developments in high liquefaction susceptible regions to dwellings and to structures that have used the least costly geotechnical techniques to eliminate or minimize liquefaction-induced ground failures (seismic zone 3).					
1801-1803 defined as 1501-1503		Use 1501-1503 for 1801-1803, respectively				
1900	For major modifications of structures, where appropriate use the least costly geotechnical technique to eliminate or minimize liquefaction-induced ground failures and/or differential settlement (seismic zone 4).					
1901-1904 defined as 1501-1504		Use 1501-1504 for 1901-1904, respectively				
2000	For major modifications of structures, where appropriate use the least costly geotechnical technique to eliminate or minimize liquefaction-induced ground failures and/or differential settlement (seismic zone 4).					
2001-2004 defined as 1501-1504		Use 1501-1504 for 2001-2004, respectively				
2100	Restrict new developments in very severe landslide or rockfall locales to open spaces (seismic zone 4). Assume code adoption, compliance, and enforcement.					
2101	defined for reinforced masonry	Use 1002				
2102	defined for c-i-p concrete	Use 1004				
2103	defined for tilt-up	Use 1006				
2104	defined for ductile pre-cast concrete frame	Use 1008				
2105	defined for wood frame	Use 1010				
2106	defined for mobile home	Use 1012				
2200	Restrict new developments in very severe landslide or rockfall locales to open spaces (seismic zone 3). Assume code adoption, compliance, and enforcement.					
2201-2206 defined as 2101-2106		Use 2101-2106 for 2201-2206, respectively				
2300	Purchase properties in severe landslide regions and replace elsewhere (seismic zone 4).					
2301-2306 defined as 2101-2106		Use 2101-2106 for 2301-2306, respectively				
2400	Purchase properties in severe landslide regions and replace elsewhere (seismic zone 3).					
2401-2406 defined as 2101-2106		Use 2101-2106 for 2401-2406, respectively				

For loss-reduction activities 1000, 1100, 1200, 1300, 1400, 2100, 2200, 2300, and 2400 -- pertaining to fault rupture, landslide -- we assume that instances of ground failure lead to total structural loss. This assumption is extreme, as limited data show in Wiggins and Taylor (1986) for fault rupture, landslide, and large flow failure and Wiggins et al. (1978) on Alleghany County landslide losses. More refined studies are needed that relate severity of loss to severity of ground failure.

For loss-reduction activities 1000 and 1200, we assume that all instances of intensity of IX and X are associated with total loss from surface faulting in active fault zones. In specific regions, these assumptions can be improved through risk studies that incorporate probabilities of various severities of surface rupture at various sites in the fault zone of deformation. A given earthquake involving the fault will not rupture at all locations along the fault trace; even where rupture occurs, the severity may be considerably less than the maximum surface displacement within the entire rupture zone. For moderately active fault zones referred to in mitigations 1100 and 1300, we assume that all occurrences of intensity X and that 50 percent of the occurrences of intensity IX result in surface faulting sufficiently severe to cause total structural loss. We make no discrimination among various types of structures with respect to their capacity to withstand various severities of fault movement. We further assume perfect knowledge of the width of the fault zone of deformation.

We make similar assumption for landslide failures. We assume that sites were perfectly identified for these potential displacements and that total constructive loss occurs given these displacements. Moreover, in loss-reduction activities 2100, 2200, and 2300, we assume that severe landslides occur whenever intensities IX and X occur. More refined probabilistic landslide models would lead to probabilities of different severities of ground failures resulting from landsliding failures; such models are currently under research.

Loss-reduction activities 1500, 1600, 1700, 1800, 1900, and 2000 deal with potential settlement/ liquefaction-induced ground failure (other than large flow failure). For these we assume, based on limited empirical data from Wiggins and Taylor (1986), that the loss expected at shaking intensity X corresponds to the loss that would occur should these ground failures occur. We further assume that differential ground displacements occur at intensities VIII, IX or X in highly susceptible liquefaction regions. This latter assumption is extremely cautious. As noted in the risk analysis report, an alternative assumption in San Mateo County is that a maximum of only two percent of locations in regions highly susceptible to liquefaction might suffer surface displacement.

In view of the numerous assumptions that we make here in order to conduct risk and decision analyses of landuse measures, one must be cautioned that the outputs will be for current policy-level discussion. Results assist in ruling out broad measures that are clearly too expensive or whose benefits are slight or in defining further socioeconomic contexts under which specific loss-reduction measures should be implemented.

NOTES FOR TABLE B-2

[1]FEMA, 1988 a-6

[2]Retrofit cost assumes that costs in Los Angeles and the rest of Zone 4 will be lower than in other seismic zones. This is attributed to contractor experience and building department competence gain in areas where retrofit is mandated by ordinance.

[3]FEMA, 1988 a-12

[4]The values for retrofit costs in FEMA Figure 12 where judged to be slightly low, particularly given the high sample bias toward military construction. A value of $15 per square foot was selected as more representative of the average for these types of buildings.

[5]FEMA, 1988 a-14

[6]BAREPP, undated - Tilt-up Building

[7]Dames & Moore experience with tilt-up retrofit is similar to that described in BAREPP document when only roof-to-wall anchorage and roof continuity ties are provided. A value of $1 to $2 per square foot is typical for one-story industrial buildings. A range of $2 to $50 per square foot represents a reasonable range for two- to three-story buildings.

[8]FEMA, 1988 a-14

[9]Sample used in FEMA reference (three buildings) is deemed inadequate and nonrepresentative. Retrofit costs for precast frames should be about the same as those for cast-in-place concrete frames in Zone 2 and up to one-third greater in the more active seismic zones.

[10]FEMA, 1988 a-7

[11]Average replacement costs taken as rough composite of reinforcement masonry and concrete shear wall low rise (one to four story) buildings.

[12]Retrofit costs obtained from contractor's estimating data.

ASSUMPTIONS NOTED IN TABLE B-3

[1]Loss data obtained from ATC-13, Table G.1. Judgmental assumptions made for each structural category are outlined in subsequent footnotes. Facility Classification numbers below are as defined in Table 3.1 of ATC-13.

[2]Unreinforced masonry "as is" damaged factor (DF) estimates are obtained using the following assumptions:

a. The average of ATC-13 Facility Class 75 (URM low-rise) and Facility Class 76 (URM medium-rise).
b. For MMI intensities VI and VII, the "mean best" estimates (MEANB) are used for each facility class.
c. For MMI intensities VIII, IX, and X, a weighted average of "mean best" (MEANB) and "mean high" (MEANH) estimates calculated as follows for each facility class.

[3]Unreinforced masonry "retrofit" damage factor (DM) estimates are obtained using the following assumptions:

a. The average of ATC-13 Facility Class 9 (reinforced masonry low-rise) and Facility Class 10 (reinforced masonry mid-rise).
b. The "mean best" (MEANB) estimates for each facility class.

[4]Unreinforced masonry "retrofit" damage factor (DF) estimates are obtained using the following assumptions:

a. The average of ATC-13 Facility Class 9 (reinforced masonry low-rise and Facility Class 10 (reinforced masonry mid-rise).
b. The average of "mean best" (MEANB) and "mean high" (MEANH) estimates for each facility class.

[5]For seismic Zones 3 and 4 "as is" damage factor (DF) estimates for cast-in-place nonductile concrete frames are obtained using the following assumptions:

a. The average of ATC-13 Facility Classes 87 (low-rise), 88 (mid-rise), and 89 (high-rise).
b. The "mean best" (MEANB) estimates are used for each of the above Facility Classes.

[6]The (retrofit) damage factor (DF) estimates are used for each of the concrete frames (cast-in-place or precast) are obtained using the following assumptions:

a. The average of ATC-13 Facility Classes 18, (ductile frame low-rise), 19 (ductile frame mid-rise), and 20 (ductile frame high-rise).
b. For seismic Zone 3 the "mean best" (MEANB) estimates are used for each facility class.
c. For Zone 2*, the average "mean best" (MEANB) and "mean high" (MEANH) estimates are used for each facility class.

[7]For Zone 2*, the "as is" damage factor (DF) for cast-in-place nonductile concrete frames are obtained using the following assumptions:

a. The average of ATC-13 Facility Classes 89 (low-rise), 88 (mid-rise), and 89 (high-rise).
b. The weighted average of "mean best" (MEANB) and "mean high" (MEANH) estimates are used for each facility class calculated as follows: (2MEANB + MEANH)/3

[8]In seismic Zones 3 and 4, the "as is" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: ATC-13 Facility Class 21, the "mean high" estimate.

[9]In seismic Zones 3 and 4, the "retrofit" damage factor (DF) estimates for concrete tilt-up buildings are calculated using the following assumptions:

a. ATC-13 Facility Class 21
b. The average of "mean low" (MEANL) and "mean best" (MEANB) estimates.

ASSUMPTIONS NOTED IN TABLE B-3 (Continuation)

[10]In seismic Zone 2*, the "as is" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: The value estimated for Zones 3 and 4 multiplied by 1.2.

[11]In seismic Zone 2*, the "retrofit" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: The "mean best" (MEANB) estimate for ATC-13 Facility Class 21.

[12]In seismic Zones 3 and 4, the "as is" damage factor (DF) estimates for nonductile precast concrete frames are obtained using the following assumptions:
a. The average of ATC-13 Facility Classes 81 (low-rise), 82 (mid-rise), and 83 (high-rise).
b. The average of "mean best" (MEANB) and "mean high" (MEANH) estimates for each facility class.

[13]In seismic Zone 2*, the "as is" damage factor (DF) estimates for nonductile precast concrete frames are obtained using the following assumptions:
a. The average of ATC-13 Facility Classes 81 (low-rise), 82 (mid-rise), and 83 (high-rise).
b. The "mean high" (MEANH) estimate for each facility class.

[14]The damage factor (DF) estimates for woodframe dwellings are obtained using ATC-13 Facility Class 1, and the following assumptions:
a. The "mean high" (MEANH) estimate for the "as is" condition.
b. The "mean best" (MEANB) estimate for the "retrofit" condition.

[15]The damage factor (DF) estimates for mobile homes are obtained using ATC-13 Facility Class 23 and the following assumptions:
a. The "mean high" (MEANH) estimates for the "as is" condition.
b. The "mean best" (MEANB) estimates for the "retrofit" condition.

[16]These estimates are derived from Wiggins and Taylor (1986) and incorporate preliminary Coalinga loss data.

NOTES FOR TABLE B-4

[1]Loss data obtained from ATC-13, Table G.1. Judgmental assumptions made for each structural category are outlined in subsequent footnotes. Facility Classification numbers are as defined in Table 3.1 of ATC-13.

[2]Unreinforced masonry "as is" damaged factor (DF) estimates are obtained using the following assumptions:
a. The average of ATC-13 Facility Class 75 (URM low-rise) and Facility Class 76 (URM medium-rise).
b. For MMI intensities VI and VII, the "mean best" estimates (MEANB) are used for each facility class.
c. For MMI intensities VIII, IX, and X, a weighted average of "mean best" (MEANB) and "mean high" (MEANH) estimates calculated as follows for each facility class.

[3]Unreinforced masonry "retrofit" damage factor (DM) estimates are obtained using the following assumptions:
a. The average of ATC-13 Facility Class 9 (reinforced masonry low-rise) and Facility Class 10 (reinforced masonry mid-rise).
b. The average of "mean high" (MEANH) estimates for each Facility Class.

[4]For seismic Zones 3 and 4 "as is" damage factor (DF) estimates for cast-in-place nonductile concrete frames are obtained using the following assumptions:
a. The average of ATC-13 Facility Classes 87 (low-rise), 88 (mid-rise), and 89 (high-rise).
b. The "mean best" (MEANB) estimates are used for each of the above Facility Classes.

[5]The (retrofit) damage factor (DF) estimates for nonductile concrete frames (cast-in-place or precast) are obtained using the following assumptions:
a. The average of ATC-13 Facility Classes 18 (ductile frame low-rise), 19 (ductile frame mid-rise), 20 (ductile frame high-rise), 5 (shear wall low-rise), 7 (shear wall mid-rise) and 8 (shear wall high-rise).
b. For seismic Zones 3 and 4, the "mean best" (MEANB) and "mean high" (MEANH) estimates are used for each facility class.
c. For Zone 2* the average of the "mean best" (MEANB) and "mean high" (MEANH) estimates are used for each facility class.

[6]For Zone 2*, the "as is" damage factor (DF) estimates for cast-in-place nonductile concrete frames are obtained using the following assumptions:
a. The average of ATC-13 Facility Classes 87 (low-rise), 88 (mid-rise), and 89 (high-rise).
b. The weighted average of "mean best" (MEANB) and "mean high" (MEANH) estimates are used for each facility class calculated as follows:

[7]In seismic Zone 3 and 4, the "as is" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: ATC-13 Facility Class 21, the "mean high" (MEANH) estimate.

[8]In seismic Zone 3 and 4, the "retrofit" damage factor (DF) estimates for concrete tilt-up buildings are calculated using the following assumptions:
a. ATC-13 Facility Class 21.
b. The average of "mean low" (MEANL) and "mean best" (MEANB) estimates.

[9]In seismic Zone 2*, the "as is" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: The value estimated for Zones 3 and 4 multiplied by 1.2.

[10]In seismic Zone 2*, the "retrofit" damage factor (DF) estimates for concrete tilt-up buildings are obtained using the following assumption: The value estimated for Zones 3 and 4 multiplied by 1.2.

NOTES FOR TABLE B-4 (Continuation)

[11]In seismic Zones 3 and 4, the "as is" damage factor (DF) estimates for nonductile precast concrete frames are obtained using the following assumptions:

a. The average ATC-13 Facility Classes 81 (low-rise), 82 (mid-rise) and 83 (high-rise).
b. The average of "mean best" (MEANB) and "mean high" (MEANH) estimates for each facility class.

[12]In seismic Zone 2*, the "as is" damage factor (DF) estimates for nonductile precast concrete frames are obtained using the following assumptions:

a. The average of ATC-13 Facility Classes 81 (low-rise), 82 (mid-rise) and 83 (high-rise).
b. The "mean high" (MEANH) estimate for each facility class.

[13]The damage factor (DF) estimates for woodframe dwellings are obtained using ATC-13 Facility Class 1, and the following assumptions:

[14]The damage factor (DF) estimates for mobile homes are obtained using ATC-13 Facility Class 23 and the following assumptions:

a. The "mean high" (MEANH) estimate for the "as is" condition.
b. The "mean best" (MEANB) estimate for the "retrofit" condition.

[15]These estimates are derived from Wiggins and Taylor (1986) and incorporate preliminary Coalinga loss data.

FOOTNOTES FOR TABLE B-5

[1]Implementation costs are costs to add seismic design as per current Uniform Building Code (UBC) in areas where seismic design is currently not practiced. In areas where limited seismic design is already implemented, costs may be taken as half of those shown.

[2]See for example (ICBO, 1980) Table 1, page 5-3.

[3]Add 50 percent to costs of measure 100 in Zone 2* as allowance for ductile detailing. Increment cost is shown here (not total).

[4]Zone 2* damage with ductile seismic provisions is taken as average of Zone 2* without ductile detailing and Zone 3. Values shown are increment loss reduction beyond 120 (not total). See Table B-4.

[5]Although the measure could affect new construction as well as existing buildings, assumed loss reductions are based on the assumption that the measure causes existing buildings to be retrofit. This is without an assessment of what fraction of all buildings of the indicated type will be so affected by this specific measure. Listed are only those key building types for which a hazardous rating is given.

[6]"As-is" loss for parapets are taken as 15 percent of "as-is" losses for unreinforced masonry, as given in Table B-4. "Retrofit" loss is taken as 10 percent of retrofit loss for URM as given in Table B-4. Loss reduction values shown are differences of the above.

[7]Loss reductions for Zone 3 essential buildings are taken as those for retrofit of existing buildings. This is based on the assumption that in most of Zone 3, seismic design is currently practiced for new buildings. However, the loss reductions for each given MMI are judgmentally taken as 80 percent of the loss reductions for Zone 4 for the following reasons:

a. Lower design forces
b. Less developed "infra-structure" of competence in engineers, contractors and construction trades in Zone 3 relative to Zone 4.

[8]For Zone 2*, it has been assumed that the results of this measure are both to obtain code level seismic design where none previously existed, and to result in the upgrade of existing buildings to some reduced criteria. Next, it is assumed that measures 100 and 120 are implemented. Therefore, the loss reductions given here are the average of loss reductions for new constructions in Zone 2* (the sum of measures 100 and 120) and the loss reduction for retrofit of existing buildings in Zone 2* (the values given for Zone 2* in measure 170).

[9]See note 8. The cost of implementing this measure is taken as the average of costs for new construction and of costs for retrofit of existing buildings in Zone 2*. Also, see Table B-2, and note 1 above.

[10]Measures 130 and 140 are less for wood-frame construction. Implementation cost is based on retrofit of cripple stud walls and foundation anchorage only.

[11]Given limited degree of retrofit as described in note 10, average loss reduction is taken as 80 percent of loss reduction estimated for remediation of all key deficiencies (those indicated in Table B-4).

[12]Average loss reduction is based on the assumption that dwelling (apartments and condominiums) loss in fire following earthquake would be complete (100 percent) for percentage of total dwelling inventory shown.

[13]Judgmentally estimated.

[14]Retrofit costs for equipment are taken as percent of equipment costs--not building.

APPENDIX C

ESTIMATION BASES FOR EFFICIENCY AND ALLOCATIVE ANALYSES

C.1 Considerations Affecting Economic Efficiency Analysis

In addition to initial outlay costs and estimates of direct property benefits for specific loss-reduction activities, we have considered the following associated costs and losses in aggregate benefit-cost analyses:

- o costs associated with temporary housing,
- o costs of and losses associated with business interruption,
- o losses associated with injuries and deaths,
- o losses associated with the cost of money (interest on loans), and
- o premium costs (if insurance is purchased).

We have not considered costs and losses associated with the following:

- o contents damage,
- o damage to and damage by water systems and losses resulting from fire following earthquakes,
- o release of toxic or hazardous chemicals,
- o transaction, foreclosure and other similar activities associated with distributive costs and losses (with special caveats for "loadings" associated with premium costs),
- o disaster cleanup, and
- o indirect economic impacts (e.g., effects on prices, unemployment, and their multipliers).

Temporary Housing Costs

If a dwelling is damaged, the homeowner may incur an additional cost if he must find alternative temporary housing. For calculation purposes, we have estimated that for dwellings damaged above 50 percent and whose structural value is $100,000, six months of temporary housing will be needed at a monthly cost of $1,000. Any percentage of damage less than 50 was linearly interpolated to adjust for the temporary housing cost. Investigations of insurance and federal disaster assistance data on temporary housing costs after dwelling damage could improve these assumptions.

due to building structure or equipment damage, as well as the unavailability of needed materials and services. For complex business operations, further analyses may be needed to determine the extent to which damage to business facilities or to pertinent infrastructure facilities may lead to business losses. In some cases, alternative buildings, equipment, materials and supplies, and sources of energy, water, gas, sewage disposal, transportation, and/or other services may be available to continue business and minimize losses.

For simplification we have assumed that business interruption is a function of

- o industry type as denoted by Standard Industrial Classification (SIC) codes,
- o the "q-ratio" of the business (this ratio is defined as the market value divided by the replacement value of the business), and
- o unemployment insurance premiums paid by the business in order to cover short-term unemployment resulting from earthquake damage.

We also have assumed that businesses whose q-ratios are less than one and who are not insured will not re-invest if the earthquake has caused significant damage. This is because the cost to re-invest -- to replace what has been damaged -- is greater than the return that the company expects to earn.

For calculation purposes we have assumed a 10 percent deductible. We have assumed further that only business owners with both earthquake property insurance and earthquake business interruption insurance will be reimbursed by insurers for business interruption losses. We have further assumed that 90 percent of business interruption loss is revenue and that the remaining 10 percent is unemployment.

<u>Losses Associated with Deaths and Injuries</u>

In order to estimate losses associated with deaths and injuries, we have developed interactive parameters for the

- o number of occupants (a function of such factors as time of day, day of week, absentee rates, square footage, and occupancy rates per square footage when fully occupied), and
- o costs of deaths, serious injuries, and minor injuries.

We have followed AIRAC, 1987 (and ultimately Whitman and Cornell, 1976) in relating moderate injuries, serious injuries, and deaths to degree of building damage. We have assumed that minor injuries cost $1,600 and that serious injuries lead to $65,000 for hospitalization and $7,500 in lost wages (see AIRAC, 1987). We have provided two qualified estimates for costs of deaths: a stringent estimate of $300,000 and another estimate of hospitalization and $7,500 in lost wages (see AIRAC, 1987). We have provided two qualified estimates for costs of deaths: a stringent estimate of $300,000 and another estimate of $1,000,000. For project purposes of emphasizing losses in an insurance context, these types of assumptions are appropriate; however, as is well known, use of such estimates should not be taken to imply that the "worth" of a life is reducible to economic terms.

Losses Associated with the Cost of Money

A potentially more controversial element used in this analysis is a real discount rate, used as a means to determine the time-value of money (after discounting for inflation). Investors, businesses, contractors, the elderly, and low-income residents, in many cases, may greatly value marginal amounts of money and so treat money as a commodity to be spent on activities with short-term, rather than long-term payoffs. These stakeholders may prefer very high discount rates, which discourage activities with long-term or uncertain benefits. In contrast, long-term perspectives may be encouraged by parties concerned with larger scale projects or with effects of past and current investments on more distant future prospects. In this perspective actual discount rates may be examined in more aggregate terms, and the real discount rate so evaluated may be lower.

In order to avoid the many and prolonged debates over the suitable discount rate, we have treated the discount rate as having a possible continuum of values. For illustrative purposes, we have developed a three-tier approach, with

- o an 8 percent real discount rate at tier 1 (good investment or expenditure of money even for many with short-term horizons),
- o a 3 percent real discount rate at tier 2 (satisfactory discount rate -- similar to that used for many public projects), and
- o a 0 percent real discount rate at tier 3 (more suitable when life-safety and other public or spillover factors are emphasized).

These discount rates are used in conjunction with interactive assumptions on the effective lifetime of an loss-reduction measure. For illustrative purposes, we have assumed that the structural shells of buildings (in contrast to total buildings, for which extensive remodeling may be done) last 80 years, and that retrofitted structural systems last 30 years. Sensitivity analyses for these assumptions have been performed and are heavily dependent on the discount rate used.

Premium Costs

In Section 2 we argued that, with the possible exception of mandated nationwide primary coverage of selected classes of buildings, probabilistic multisite methods are needed for estimating earthquake insurance rates. These methods incorporate surplus development, expected annual losses, and catastrophic loss potential -- all critical elements in determining the ability of an insurance program to pay off claims as they arise. These methods thus provide means to account for the catastrophic loadings needed for earthquake rates, yet unlike PML methods do not do so at the expense either of not covering expected annual losses or of providing lower rates for higher risks and vice versa.

A prima facie argument can also be developed that mandated national rates (for selected classes of buildings) can, in theory, reduce rates through geographic dispersion which reduces program disturbances caused by rare but catastrophic losses. It is also possible to argue that government involvement in a tax-free reserve fund may provide possible lower rates since greater available reserves reduce the likelihood of insufficient reserves to cover catastrophic losses.

Details of the following matters extend beyond the project scope:

- o administrative, mapping, and other program costs
- o verified behavioral models (e.g., models of the efficiency of private versus public sector involvement, models of response to risk-based versus non-risk-based premiums, models of voluntary purchase of earthquake insurance)
- o careful consideration of intergenerational transfers for any proposed federal program (including transfers that result from making rates initially attractive)

Hence, assumptions made in this project concerning premium costs are crude. These assumptions considered a general loading on expected annual losses (the loading is a function of uncertainties, administrative costs, taxation of reserves, fees, variances of loss distributions, and other possible factors), but do not consider, for instance, effects of risk-based premiums on inducing loss-reduction activities and other factors associated with general federal insurance program construction. In a fuller study of federal earthquake insurance feasibility issues, modeling of these effects would be critical.

C.2 Bases Underlying the Economic Allocative Analysis

In order to develop estimates of costs and benefits to diverse stakeholders, we have included the following stakeholders in our interactive model:

- o owners,
- o mortgage lending institutions,

- o government (federal, state, and local),
- o the federal taxpayer,
- o the state taxpayer,
- o the local taxpayer,
- o insurance companies (covering quake and non-quake, respectively), and
- o employees.

As a result of project workshop discussions, we have also informally included tenants as stakeholders deserving special consideration. For estimating how costs, losses and benefits are distributed among these various stakeholders, we have used or developed provisional models for estimating

- o mortgage default losses,
- o general liabilities, and
- o governmental costs (disaster relief claims).

Mortgage Default Assumptions

The general logic of mortgage default is fairly well understood from the standpoint of lending institutions. Following an earthquake, owners whose property damage exceeds (post-disaster) equity may, all other things being equal (such as q-ratios), decide to default. Should default occur in these cases, lending institutions will sustain part of the loss (remaining mortgage balance plus repair costs plus administrative and transaction costs minus sale value). For simplification, we have assumed that post-earthquake equity (after repairs) equals pre-earthquake equity, and that the property owner will default if the property damage exceeds this equity. Owing to appreciation in land values and to reductions in remaining mortgage balances, after some number of years (perhaps 15 for average land appreciation values given a 30-year mortgage), the equity value is assumed to be greater than any property damage (soil foundation damage excluded). Hence, equity position is a critical interactive parameter affecting potential losses to lenders.

General Liability: Property Damage

It is assumed that the general liability property damage loss potential for earthquakes can be approximated by use of loss-cost factors that were developed using information supplied by members of the AIRAC Earthquake Losses Subcommittee (AIRAC, 1987). These factors are listed in Table C-1 for buildings (excluding single family dwellings) that sustain various degrees of earthquake damage including extensive damage (5 percent to 19 percent value lost), major damage (20 percent to 79 percent value lost), and "total" damage (90 percent to 100 percent value lost).

Table C-1
Loss-Cost Factors for Liability
(AIRAC, 1987)

Possible Outcomes	Degree of Building Damage Extensive 0.05-0.19	 Major 0.20-0.79	 Total 0.80-1.00
Percent with a Claim	0.05	0.37	0.72
Non-suit-pay			
Percentage	0.35	0.30	0.20
Average Amount	360,000	1,300,000	5,000,000
Suit-pay			
Percentage	0.13	0.18	0.31
Average Amount	725,000	2,625,000	10,000,000
Suit-CWP*			
Percentage	0.10	0.15	0.24
Average Amount	175,000	435,000	1,300,000
Non-suit-CWP*			
Percentage	0.42	0.37	0.25
Average Amount	87,000	220,000	650,000

CWP*: Closed without payment

General Liability: Injury Losses

The size of general liability injury losses are also approximated by applying loss-cost factors that were developed based on information supplied by members of the AIRAC Earthquake Loss Subcommittee (AIRAC, 1987). Our estimates of life and injury-related losses are used to determine how many people would sustain minor, major, or fatal injuries and these figures are then used along with estimated percentages of claims filed and settled, with and without pay, to calculate general liability bodily injury losses for our spectrum of possible earthquakes. The numbers used to calculate the general liability bodily injury loss potential are illustrated in Table C-2.

Table C-2
Estimates Used for General Liability
. Bodily Injury Loss Potential
(AIRAC, 1987)

	Minor Injury	Major Injury	Fatality
Percent with a Claim	0.15	0.50	0.50
Non-suit-pay			
Percentage	0.34	0.28	0.20
Average Amount	7,000	120,000	177,000
Suit-pay			
Percentage	0.14	0.20	0.31
Average Amount	19,000	205,000	350,000
Suit-pay			
Percentage	0.11	0.16	0.25
Average Amount	5,500	28,000	25,000
Non-suit-CWP*			
Percentage	0.41	0.36	0.25
Average Amount	750	1,600	3,000

CWP*: Closed without payment

General Liability: Workers' Compensation

Workers' compensation is a compulsory system that requires employers to provide no-fault insurance against on-the-job injury and disease, in return for a limited liability against such events. Employers can meet their obligation in three ways: (1) self-insure, (2) purchase insurance from a private carrier, or (3) purchase insurance from a state insurance fund. Not all three options are available in all states. Eighteen states maintain state funds that sell workers' compensation insurance. Six of these are monopolies in states that bar private carriers from selling workers' compensation insurance. The remaining twelve state funds compete with private carriers for business (Butler and Worrall, 1986). To allocate workers' compensation costs between the insurance industry and the government, we have made the simplifying assumption that 70 percent of the costs are borne by private industry and 30 percent are borne by state governments.

Workers' compensation loss potentials can be very roughly approximated by applying loss-cost factors to the estimated overall number of fatalities and minor and serious injuries to persons covered who are at work during the earthquake. Most firms are unable to self-insure either because they are small or because they do not meet the requirements of the state law and, therefore, must buy insurance from either a private carrier or a state agency. It is assumed that 80 percent of employees are covered by workers' compensation insurance and thus that 80 percent of the life and safety costs experienced by a business are covered by workers' compensation insurance. Hence, overall, 56 percent of workers' compensation losses are assumed to be borne by private insurers, 24 percent by government insurance, and 20 percent by workers themselves (less the portion covered by liability).

<u>Governmental Costs</u>

In assessing status quo governmental liabilities as well as governmental liabilities under various forms of earthquake insurance involvement, we have explicitly modeled

- o For homeowners, Small Business Administration (SBA) subsidies in the form of 4 percent, 30-year loans to individuals who do not have credit elsewhere (these apply after a disaster and imply that insurance does not cover the needed funds for repair).
- o For individuals who do not qualify for SBA disaster loans, FEMA sponsors the Individual and Family Grant Program (IFGP) in conjunction with state and local governments; this program provides up to $10,400 (indexed to the CPI for the future) for immediate and necessary expenditures; the average grant is between $2,500 and $3,000 and the program is 25 percent state funded and 75 percent federally funded. (State matching funds may be available in some instances.)
- o For publicly owned buildings, 75 percent federal grants are made in declared disaster areas.

We have not explicitly modeled 8 percent SBA loans to individuals or to businesses affected by disaster. Nor have we modeled general disaster clean-up costs, other than repair of damaged structures.

<u>Stakeholder Costs</u>

In order to distribute both aggregate and allocative costs and losses among various stakeholders, we have assumed that the **general taxpayer** pays those costs modeled for the federal government and that the State or local taxpayer pays those costs modeled for the specific State or local government. These distinctions are made, for instance, because specific states and local governments may transfer earthquake costs to the federal government. As a result, contributions to earthquake costs are not directly in accordance with the risks borne in specific states and municipalities. For state-owned buildings, we have assumed that liability claims may arise as modeled above.

For **insurers** we have assumed that non-quake insurers (and reinsurers) cover various non-quake losses (e.g., fire following, fatalities, workers' compensation, general liability, auto damage, theft). Quake insurers and reinsurers cover damage to structures and contents and any business interruption or temporary housing costs less deductibles and up to limits of liability. These costs are netted against premium income.

For **homeowners** we assume the following costs:

- o the insurance premium costs if they bought insurance,
- o the mitigation cost if they engaged in mitigation,
- o the deductible or amount of earthquake loss, whichever is less if they have insurance (limits of liability are ignored or this analysis),
- o the total cost of damage if they do not have insurance, and
- o the (real) interest on loans necessary to fix any damage.

If homeowners default on their outstanding mortgage, they will lose the equity value in their homes (and bear higher financing costs in the future owing to a bad credit rating). If the homeowners receive grants, this is subtracted from their costs.

Lending institutions are modeled as bearing mortgage default losses as discussed previously. If building owners have insurance we assume that no default occurs since, as a condition of the policy, the claims payment is made to the lender.

Business owners bear the following costs:

- o the insurance premium if they buy insurance,
- o the mitigation costs if they undertake mitigation,
- o the deductible or amount of earthquake property loss, whichever is less, if they buy insurance,
- o the total earthquake loss if they do not buy insurance,
- o the (real) interest on any loans necessary to fix damage,
- o business interruption losses, to the extent that they are not covered by insurance (or otherwise to the extent that there is a deductible or co-insurance clause), and
- o general liability costs, both for bodily injury and for property damage not covered by insurance, or else by a deductible and/or a co-insurance clause.

APPENDIX D
FEDERAL FINANCIAL ASSISTANCE CONSIDERATIONS IN IMPLEMENTING LRMs

In this appendix, we use an illustration in order to show that

- o on the positive side, current federal policies can be used to justify federal assistance and other programs to implement LRMs that in turn will reduce expected federal liabilities, and
- o federal disaster relief policy, regardless of its advantages, currently constitutes a major disincentive to loss-reduction for public and selected private nonprofit buildings,
- o socioeconomic tools such as those developed in this project can be used to evaluate specific programs and proposals to estimate how much federal assistance may be warranted for specific LRMs targeted to reduce expected federal liabilities.

In order to illustrate these conclusions, we have selected an extreme case in terms of building risk. This case represents a public building in seismic zone 4 and with high soft soil site shaking factors (I_{500} = 10, b = -1.1 in Table B-1). We have assumed that the building is an unreinforced masonry (URM) structure, with a remaining 80 year lifetime. Following advice from workshop participants, we have used a three (3) percent real discount rate. Building replacement value has been estimated at 5 million dollars. Other assumptions are found in Appendices B and C. In particular, seismic retrofit cost has been estimated at 25 percent of replacement value and is interpreted as a one-time up-front cost. Hence, as a result of high estimates for the frequency of earthquake intensities, relative to other seismic mitigations for URM construction, benefits will be high (or upper bound). However, relative to LRMs for other selected types of construction, such a concrete tilt-up or wood frame structures, seismic retrofit costs are high. Moreover, costs of seismic mitigations for new construction are far less than for seismic retrofit. Hence, if federal assistance programs make sense for seismic rehabilitation, they make even more sense for new construction.

Table D-1 summarizes benefits and costs of the proposed seismic LRM. Benefits include clear economic benefits of reduced workers' compensation claims. As noted in Appendix C and Section 4, the analysis here does not consider the widest range of possible benefits.

Table D-1

Expected Losses and Benefits of Illustrative Seismic Retrofit

	Expected Losses (Property only)		Expected Benefits or Reduced Losses
	No LRM	LRM	
Annual	$157,600	$96,700	$60,000
Lifetime (3% real discount rate; 80 yrs)	$4,807,200	$2,907,700	$1,899,500

Table D-1 thus illustrates that with a 3 percent real discount rate the proposed LRM has a favorable benefit-cost ratio (1.9: 1.25). With a higher real discount rate, the benefit-cost ratio would be less favorable. With a wider range of benefits included, the benefit-cost ratio would be more favorable.

A favorable benefit-cost ratio does not entail that the benefit-cost ratio is favorable for the owner. In the case of privately owned structures, some of the benefits may accrue to others, such as buildings tenants and visitors. In this illustrative case, we distinguish among the following stakeholders:

- o the local taxpayer -- or the taxpayer insofar as he pays taxes to a specific municipality and so pays for local government expenditures not otherwise funded, and
- o the federal taxpayer -- or the taxpayer insofar as he pays for federal government expenditures.

We have assumed that 75 percent of the expected property (non life-safety) losses are borne by the federal taxpayer and that 25 percent are borne by the local taxpayer. After other earthquakes in the future (see Olsen et. al., 1989), no state or Presidential declaration may be made.

Based on these assumptions, we develop the stakeholder analysis as indicated in Table D-2.

Table D-2

Stakeholder Expected Losses and Benefits from Proposed LRM

	Expected Losses		Benefits (Reduced Losses)
	No LRM	LRM	
Local Taxpayer o 25% of property damage o life-safety o total	 $1,202,000 $1,017,000 $2,219,000	 $727,000 $239,000 $966,000	 $475,000 $778,000 $1,253,000
Federal Taxpayer	$3,605,000	$2,181,000	$1,424,000
Total	$5,824,000	$3,147,000	$2,677,000

Unlike Table D-1, Table D-2 includes an economic assessment of life-safety losses in terms of workers' compensation claims and the like. Given these life-safety economic considerations, the overall benefit-cost ratio of the project is 2.1, or very favorable. Even greater benefits include not only decreased disaster relief costs but also many programmatic advantages of local skilled labor working on a cost-effective project that has important symbolic value for other projects in the local jurisdiction.

However, Table D-1 also shows that for the local jurisdiction, if life-safety considerations are ignored, the benefit-cost ratio is unfavorable (0.6) to the local jurisdiction. Thus, owing to disaster relief assistance availability, benefits of such a seismic mitigation for the state or local government will be less than the costs. Put more succinctly, <u>the presence of disaster relief greatly weakens economic arguments for state or local governments to undertake LRMs</u>. A large share of the potential property losses are "externalized," in this case to the federal government. Incentives for state and local loss-reduction programs are accordingly seriously weakened.

Put positively, Table D-2 shows how a program of federal assistance can be justified to reduce existing contingent federal liabilities. In the extreme case being analyzed, the federal government can provide full assistance to the state and local government to undertake the loss-reductions, and still have a favorable expected effect in reducing the deficit (the benefit cost-ratio is 1.27). In the vast majority of cases in which the overall benefit-cost ratio is favorable, federal cost-sharing can be estimated which nonetheless has a favorable benefit-cost ratio. Hence, although some may desire the use of sanctions to induce state and local governments to undertake cost-effective LRMs, a program of targeted federal cost-sharing may also be warranted, with both potential deficit-reducing and symbolic benefits.